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Why Are Residential PV Prices in Germany So Much Lower Than in the United States?

A Scoping Analysis

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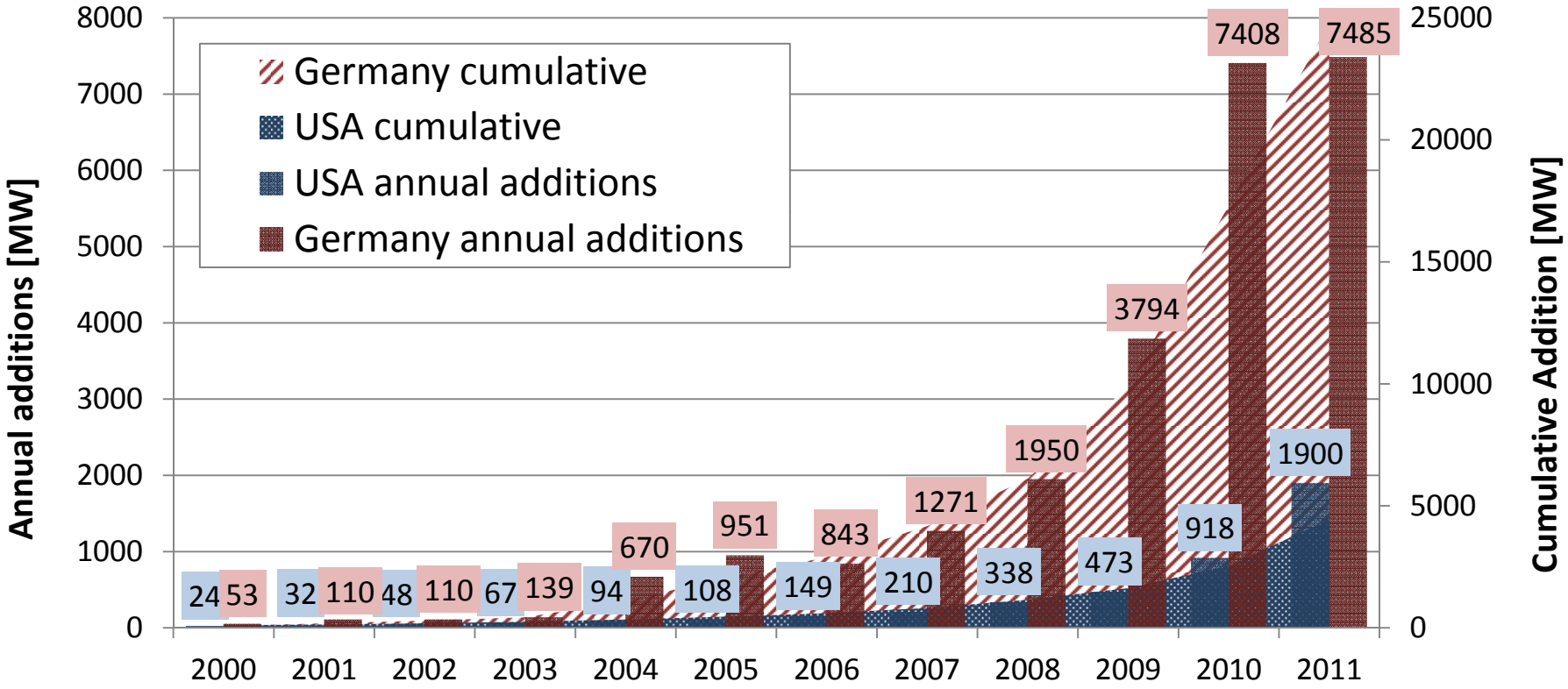
Motivation, Scope, and Limitations

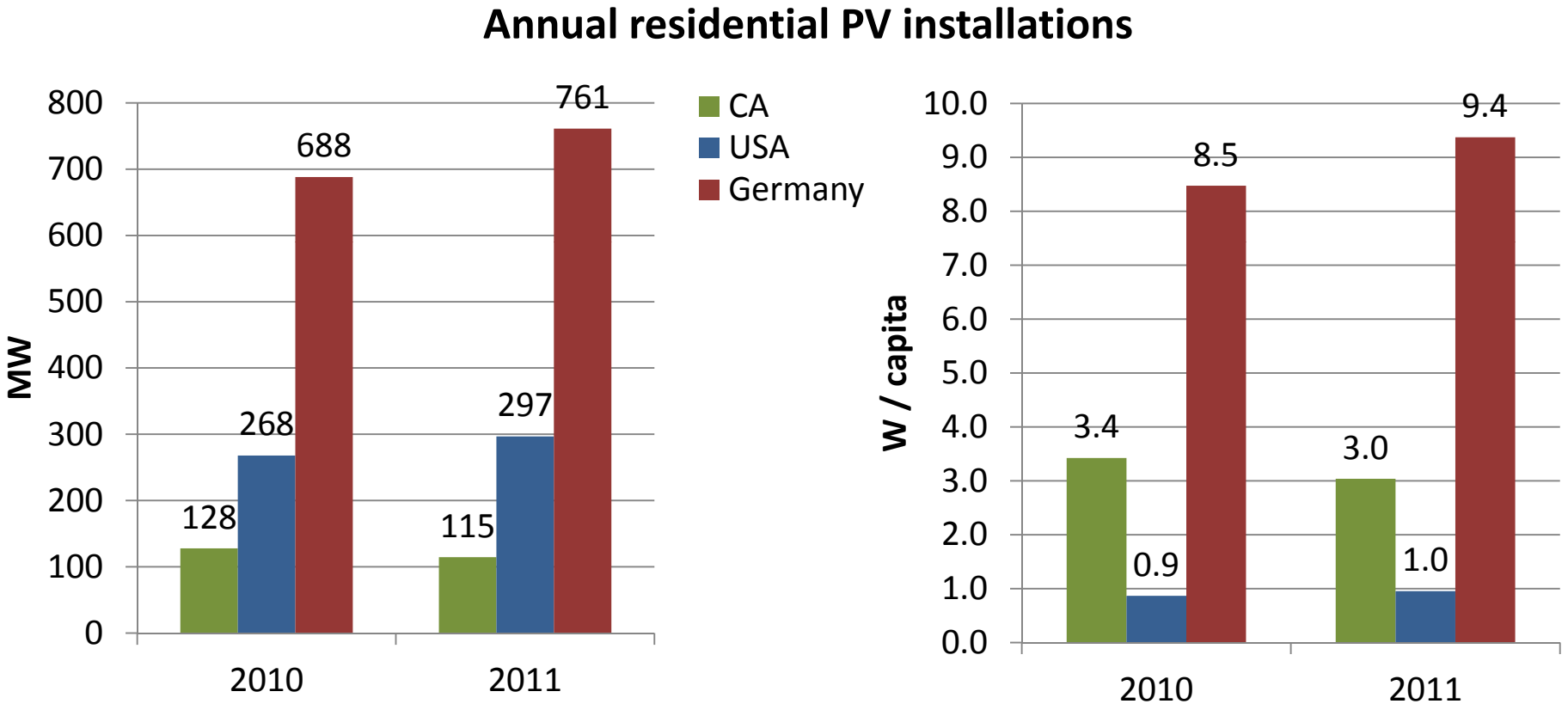
- The installed price of residential PV is significantly lower in Germany than in the U.S., due primarily to differences in "soft" costs
  - But relatively little is known about how/why soft cost components differ
- In order to better characterize the nature of these differences, LBNL:
  - Fielded a survey of German PV installers, adapted from NREL's survey of U.S. installers, to collect data on residential PV soft costs
  - Comprehensively reviewed public and private consultant data relevant to the cost structure of residential PV in Germany
- Focus is the pre-incentive price paid for customer-owned systems
  - Residential PV in Germany is almost entirely customer-owned; substantial third-party ownership in U.S. but pricing sometimes impacted by appraised values
- Analysis here is intended to be a "first cut" and serves to highlight specific areas where further research could reveal additional insights
  - Survey focus was on quantifying differences in specific business process costs
  - Additional research needed to confirm and characterize differences in more detail, as well as to link observed differences to underlying market drivers

Germany's 2011 Additions ~4x Greater, and Cumulative Additions More than 5x Greater, than in United States



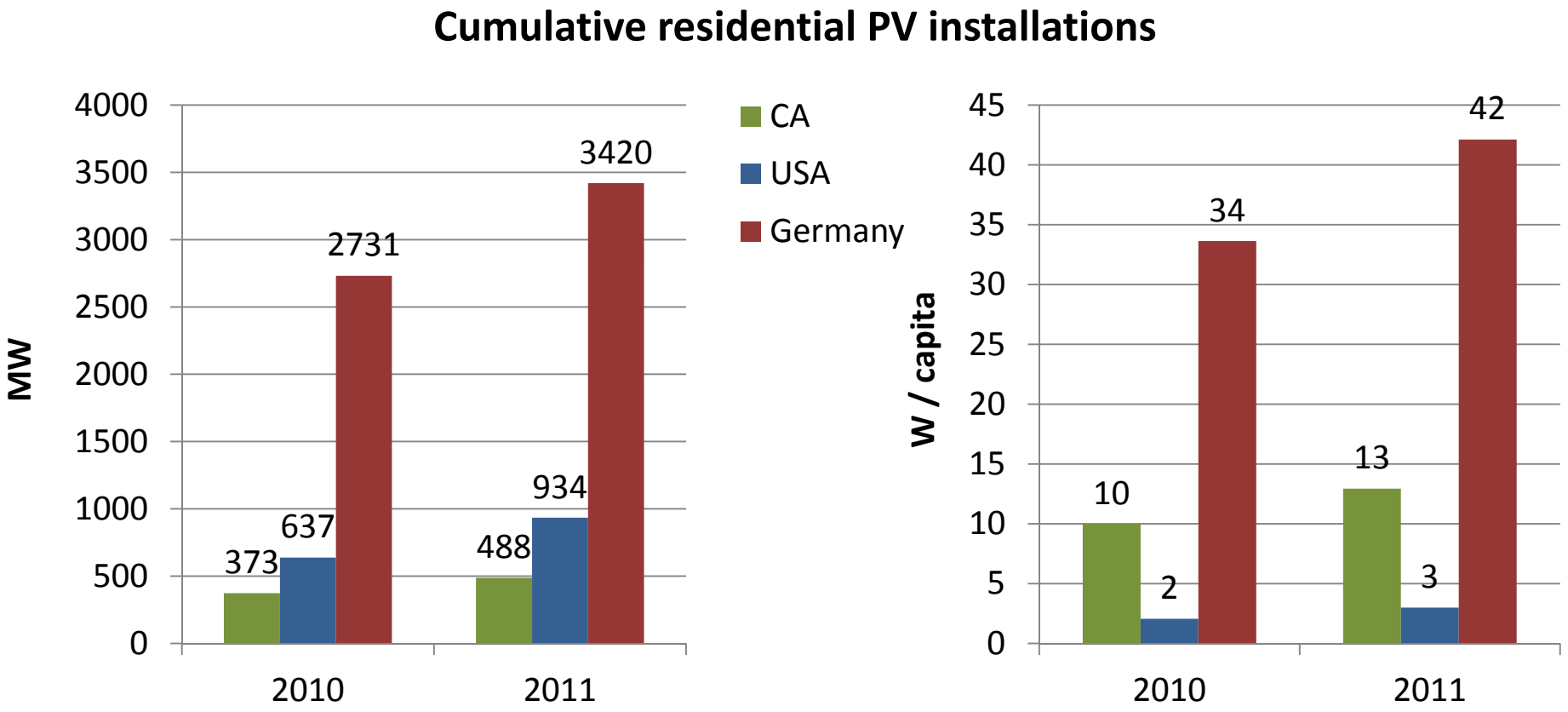
Data Sources:
US: IEA and GTM/SEIA; Germany: BNetzA (Federal Grid Agency)

Annual Residential Installations in Germany 2.5x Greater (9.4x Greater on per Capita Basis) than in United States



Data Sources:
US: GTM/SEIA; Germany: BNetzA (Federal Grid Agency)

Cumulative Residential Installations in Germany 3.6x Greater (14x on per Capita Basis) than in United States

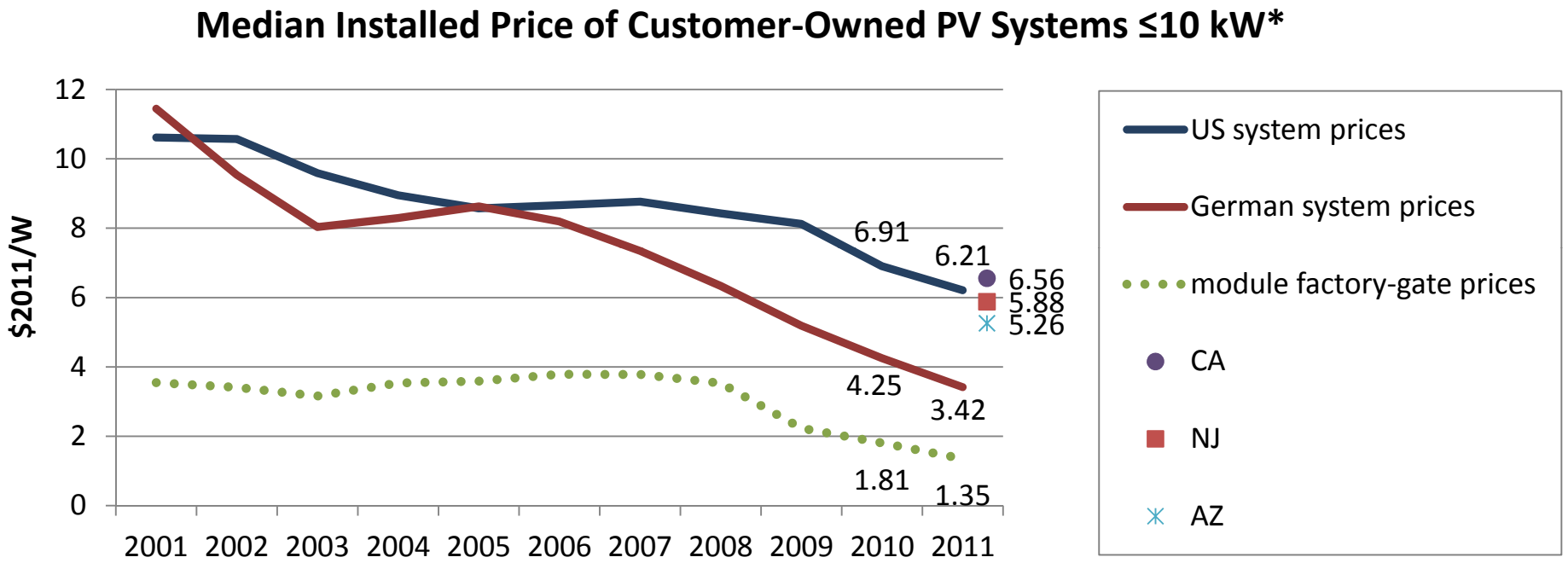


Data Sources:
US: GTM/SEIA; Germany: BNetzA (Federal Grid Agency)

Varied Data Sources Are Available for U.S. and German PV System Pricing

- **LBNL Tracking the Sun (TTS)**: Installed prices for ~70% of PV capacity installed in the U.S. from 1998-2011
- **NREL Cost Modeling Team**: Quarterly bottom-up installed price benchmarks based on interviews with installers and modeling
- **EuPD**: Project-level price quotes collected through quarterly survey of German installers (since 2008); used for BSW price reports
- **Photon, other consultants**: Installed price benchmarks based on interviews with installers or other market research
- **Miscellaneous**: Schaeffer et al., 2004, "Learning from the Sun"; Haas, 2004, "Progress in Markets for Grid-Connected PV Systems in the Built Environment"; Credit Agency for Reconstruction (KfW); IEA National PVPS reports; Langen 2010

Residential PV System Prices Have Often Been Higher in the U.S. Than in Germany



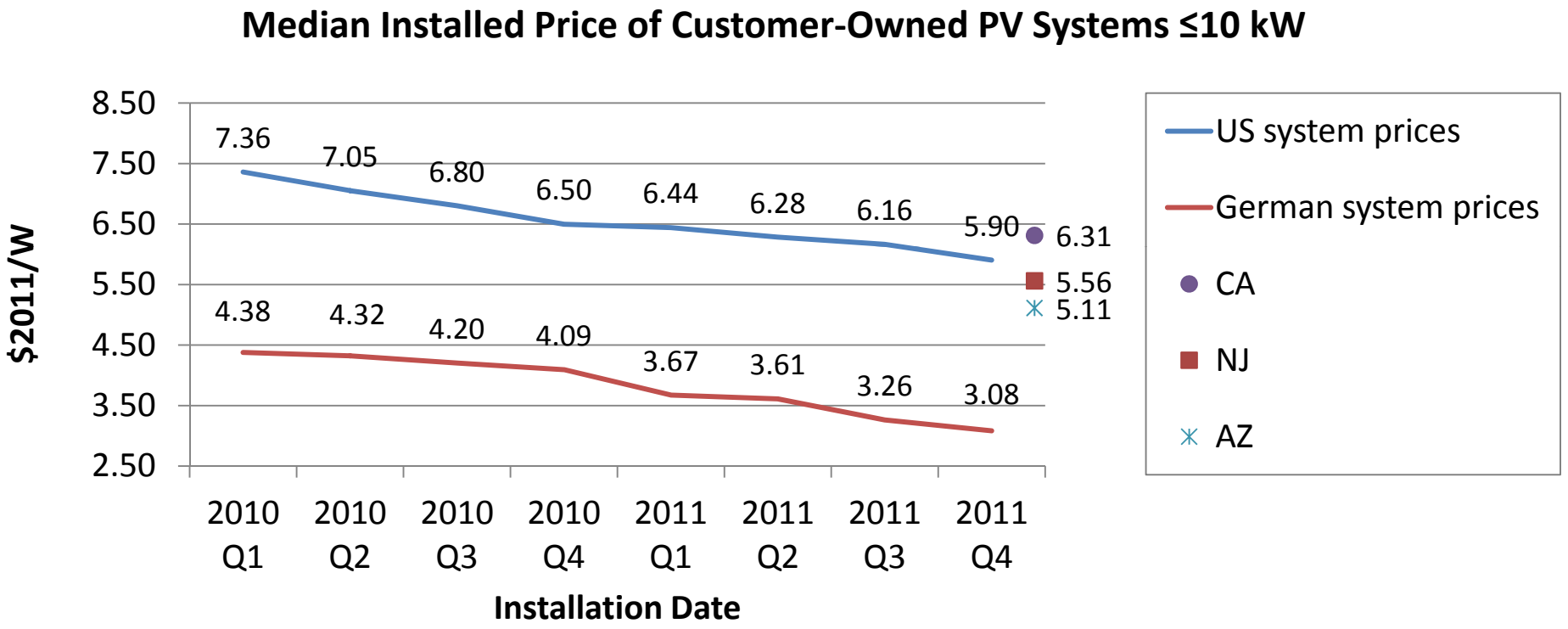
* **Note**: Focusing on systems ≤10kW serves as a proxy for the residential market, as the project-level installed price data for German systems used for this figure do not include host customer type

Data Sources:

U.S. System Prices are derived from LBNL's TTS dataset and are equal to the median of customer-owned systems ≤10kW installed in each year. ***German System Prices*** are the averages of individual price quotes in EuPD's dataset (2008-2011) or the average of prices reported by IEA, Photon, KfW, and Schaeffer (2001-2007).

Module Factory-Gate Prices are the average of prices reported by IEA, GTM, IRENA, Navigant, and Photon (annual currency exchange rates were used for module prices estimates)

As of Q4 2011, the Installed Price Differential Was About $2.8/W

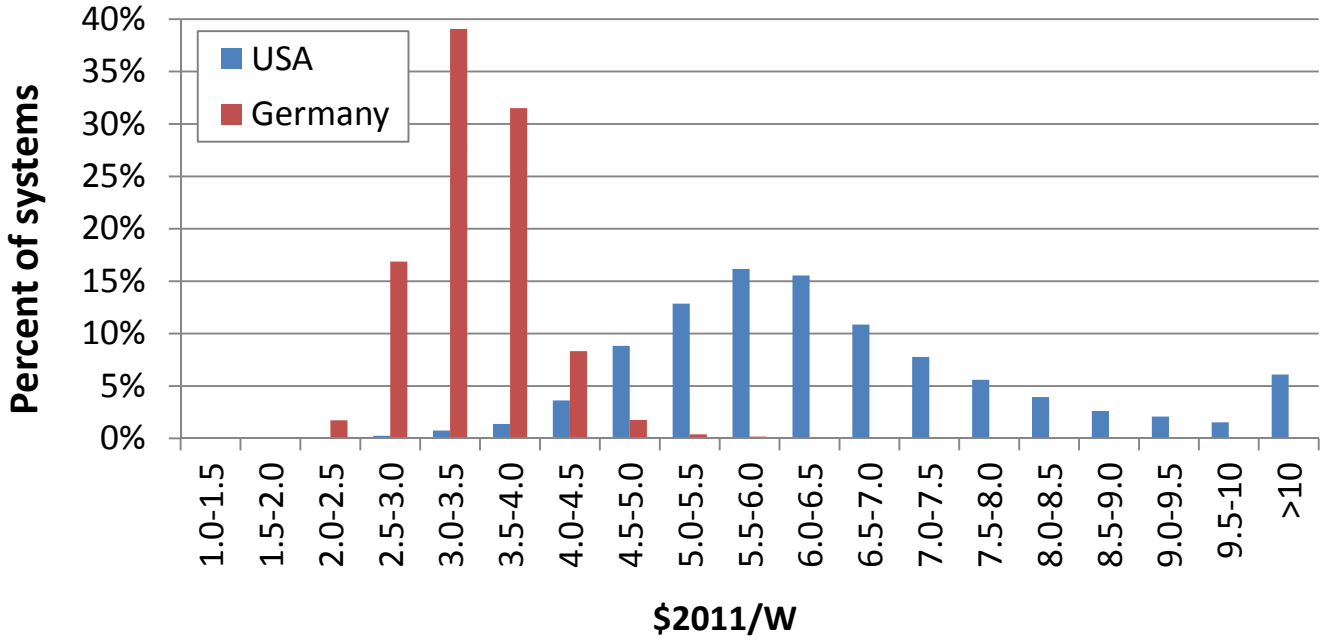


***Note**: German system prices are available based on the date of price quote, rather than by installation date. However, the average time lag between price quote and installation date is much shorter in Germany than in the US., as described further within the secondary analysis

Data Sources: US: TTS; Germany: EuPD

Installed Prices in the U.S. Are Also Much More Varied Than in Germany

Frequency Distribution:
Installed Price of ≤10 kW Customer-Owned Systems Installed in 2011



- Some U.S. systems have reached German prices already
- Greater variation in the U.S. indicative of greater market fragmentation across jurisdictions

***Note**: German data come from a survey of system price quotes from roughly 100 installers per quarter, and are thus based on a much smaller sample than the US data and may not reflect the full extent of price variability in the German market.

Data Sources: US: TTS; Germany: EuPD

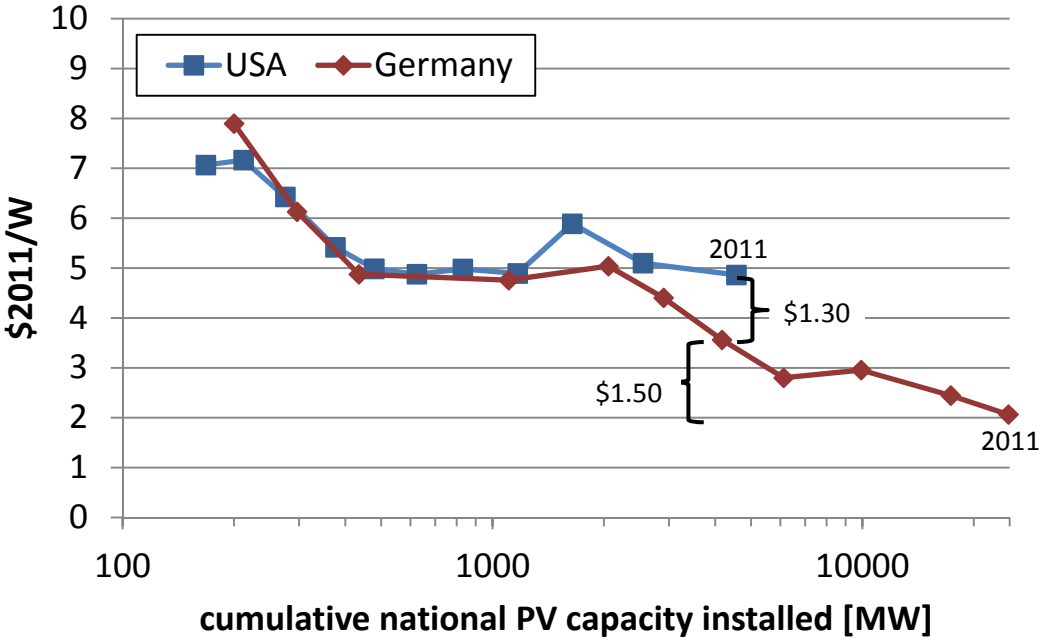
Learning Curve Analyses of BoS Costs

Question: To what extent are lower BoS costs in Germany potentially due to larger overall market scale and associated learning-induced cost reductions?

- Traditional PV learning curve analyses often focus on PV **modules** and relate **global** module production and module prices
- Some business process costs (e.g., installation labor, customer acquisition) may also be subject to **local** learning effects
- We compare the relative impact of local BoS learning in the U.S. and Germany based on implied non-module costs for <10 kW PV systems and cumulative national PV capacity installed
- BoS progress ratios may help predict future U.S. price reductions that accompany larger market scale

Differences in Market Size Alone *May* Explain Roughly Half of the Price Gap

Implied Average Annual Non-Module Costs* vs. Cumulative Capacity:
Customer-Owned Systems ≤10 kW, 2001-2011



* ***Note***: Implied average annual non-module cost = average annual system price minus global average factory gate module price

Data Sources: See slide 8.

- Total non-module costs in 2011 were ~$2.8/W higher in the U.S. than in Germany
- But, at the same cumulative capacity that the U.S. had installed at the end of 2011 (4 GW), non-module costs for residential PV in Germany were only $1.3/W less than in the U.S.
- One might (crudely) infer that the remaining $1.5/W of the total gap in 2011 non-module costs may be due simply to the larger base of German experience

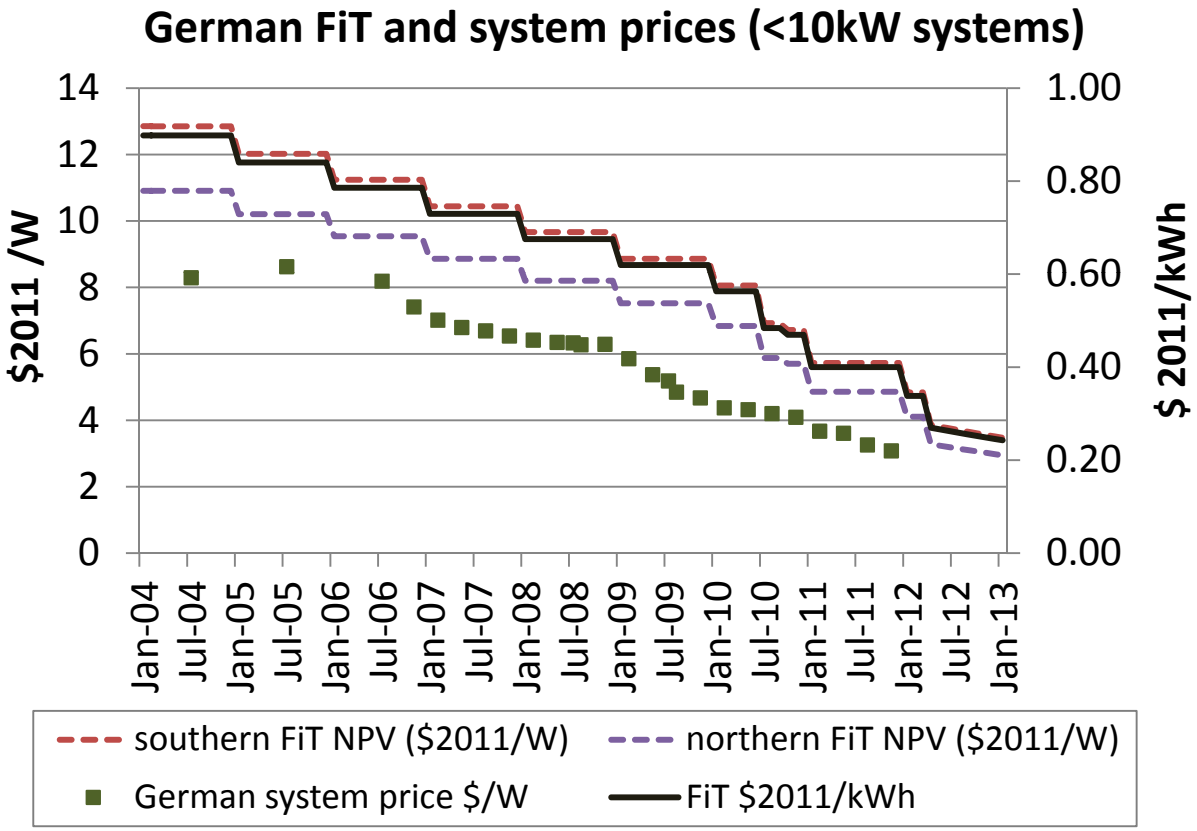
Soft-Cost Learning for <10 kW Systems Occurs More Slowly in the U.S. and Is Less Effective

Regression variable (2001-2011)		United States	Germany
Global level cumulative installations (all PV systems, not just residential)	Total system prices	PR: 91.7%, R2: 0.90	PR: 82.1%, R2: 0.92
	Non-module costs	PR: 94.2%, R2: 0.48	PR: 79.7%, R2: 0.95
Country level cumulative installations (all PV systems, not just residential)	Total system prices	PR: 90.4%, R2: 0.92	PR: 86.9%, R2: 0.83
	Non-module costs	**PR: 93.3%, R2: 0.48**	**PR: 84.6%, R2: 0.91**

** **Notes:** PR* is the Progress Ratio, defined as 2^(slope of line of best fit of log-log plot).

- The development of non-module costs is less correlated with market growth in the US than in Germany (52% vs. 9% explained by other factors)
- The learning rate for non-module costs (proxy for soft costs) is lower in the US than in Germany (7% vs. 15%)

Regular FiT Adjustments Pressure German Installers to Reduce Prices



Data Sources: EuPD (2008-2011), IEA, KfW, Photon

- BNEF (2012) indicates the presence of value-based pricing in both the US and Germany
- Following this hypothesis, the iterative reduction of the FiT presses German installers to lower system prices to maintain attractive investments for their customers
- Similar forces may operate less efficiently in the U.S., yielding higher "value-based" prices, even for customer-owned systems

Hypotheses Explored for Why German and U.S. Residential PV Prices Differ

- General:
  - Residential systems are larger in Germany→ yes
  - US installers develop projects more slowly → yes (semi-addressed)
  - US installers have higher net-profit margins, after recovering all overhead expenses → likely (semi-addressed)
- Component costs:
  - Hardware component costs are lower in Germany → possibly true for inverters, but uncertain (semi-addressed)
  - US has a lower share of cheaper Chinese modules → no
- Customer acquisition:
  - US installers have higher customer acquisition costs → yes
  - US installers have lower customer success rates → yes
  - US installers have higher marketing and advertising costs → yes
- Installation labor:
  - US installers need longer for the installation process → yes
  - US installers have higher wages → yes for installation labor, no for other labor (semi-addressed)
- Permitting, Interconnection and Inspection Costs
  - US installers have higher labor hour requirements for PII → yes
  - US has higher permitting and interconnection fees → yes
- Taxes
  - The US charges higher sales taxes on PV systems than Germany → yes

Additional Hypotheses Not Explored Here

- Overhead costs
  - US has higher business overhead costs (e.g. insurance costs, material storage costs)
  - German installers have higher sales volume per year, spreading fixed costs over larger denominator and profiting from economies of scale, allowing for volume discounts
  - US installers have higher cost of capital for their own business operations
  - US installers face higher transaction costs associated with arranging financing for customers
  - US has a longer supply chain for PV modules and other hardware
- Profit margins
  - US has a lower degree of competition among installers, maintaining higher profit margins
  - Value based pricing allows for higher prices in the US, given better irradiation, high retail rates in some regions, and more generous subsidies
- Regulatory issues
  - US requires each panel and rack component to be grounded to the DC switchbox leading to higher material costs and installation labor hours
  - Less onerous requirements for roof mounting structures
- Installation timing
  - US systems are installed more steadily throughout the year, whereas German installations were traditionally concentrated at the end of the year when prices are lower, leading to seemingly lower annual price averages
- Exchange rate dynamics are more beneficial for German system costs

A Small Body of Literature Explores the German-U.S. PV Price Gap

- Few have sought to explain the underlying reasons behind the German-U.S. PV price gap or to quantify differences in specific soft costs
  - Photon 2011a, Photon 2011b, BNEF 2012, Langen 2010, Podlowski 2008, Goodrich et al. 2012
- Possible reasons for the price gap that have been postulated:
  - "Value-based pricing" in the U.S. (e.g., associated with more generous subsidies and/or less competition among installers)
  - Preference for premium products in the U.S.
  - Lower customer-acquisition costs in Germany due to simpler/more certain value proposition (FiT), critical mass of demand, and economies of scale
  - Lower installation labor costs in Germany due to greater experience and economies of scale
  - Lower permitting costs in Germany due to fewer requirements and greater standardization
  - Less onerous electrical requirements and interconnection processes in Germany
- Our analysis complements that literature by:
  - Deriving estimates for specific business process costs via a survey of 24 German residential installers
  - Using large samples of system prices to compare price developments and distributions
  - Estimating the impact of differences in project development times on reported prices
  - Analyzing residential module market composition
- Complements NREL cost modeling team efforts that draw on in-depth interviews with installers

Survey Results

LBNL Survey of German PV Installers

- Overview of survey approach
- Sample characterization
- Survey respondents' build-up of installed price
- Individual business process costs (with comparisons to NREL survey of U.S. installers*)
  - Customer acquisition costs
  - Permitting, interconnection and inspection
  - Installation labor costs
- Sales/value-added tax for PV

* Note that a slight temporal misalignment exists, as the NREL survey of U.S. installers was focused on 2010 installations, whereas the LBNL survey of German installers was focused primarily on 2011 installations.

Overview of Survey Approach

- German survey focuses on standard DOE soft cost categories:
  - Customer acquisition
  - Permitting, interconnection, inspection
  - Installation labor
- Adapted from NREL survey of U.S. installers to allow comparisons
  - Average labor hours per system for PII and installation
  - Total annual expenditures on customer acquisition

Installer Survey Sample

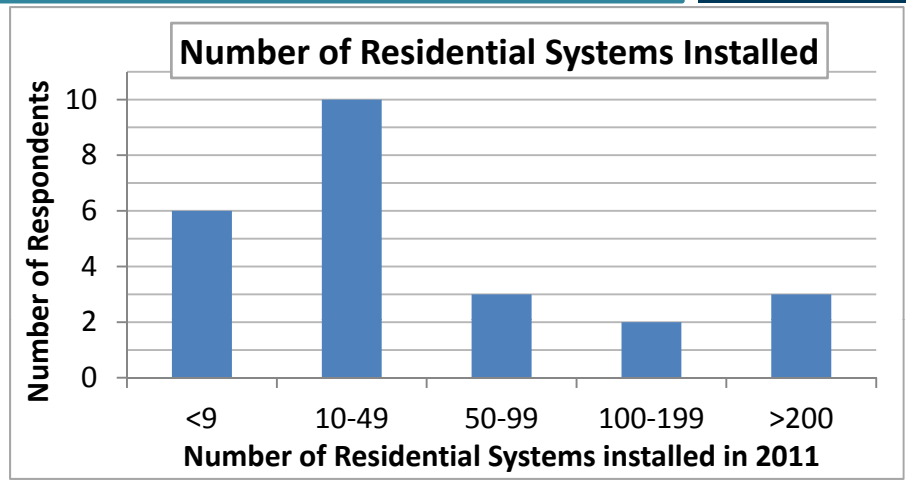
	Germany 2011	U.S. 2010*
Residential installers	24	56
Residential systems	2056	6038
Residential capacity [kW]	17,819	34,396

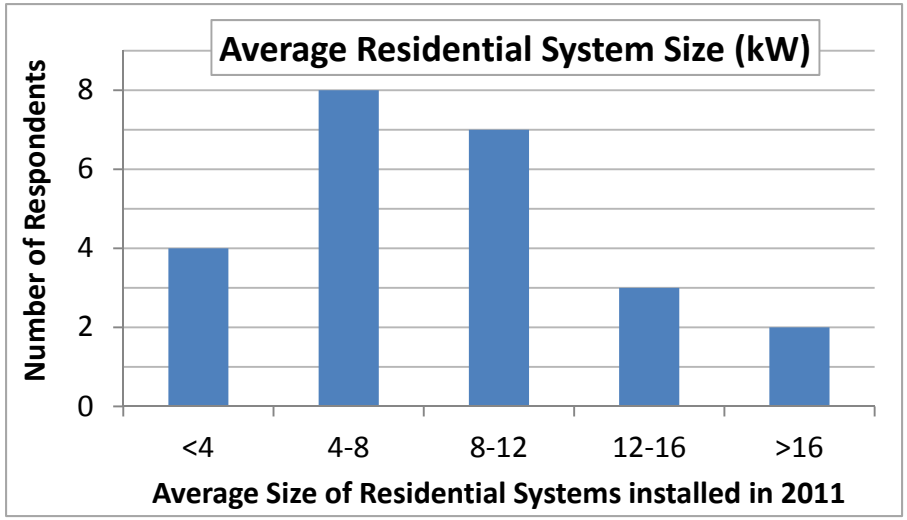
* Sample sizes shown for U.S. 2010 refer to analysis by Ardani et al. 2012

- Respondents asked about costs of **residential** systems **installed in 2011**
- Survey instrument, written in German, distributed by email to 300 German residential installers and fielded online via www.photovoltaikstudie.de

Raw Sample Characterization

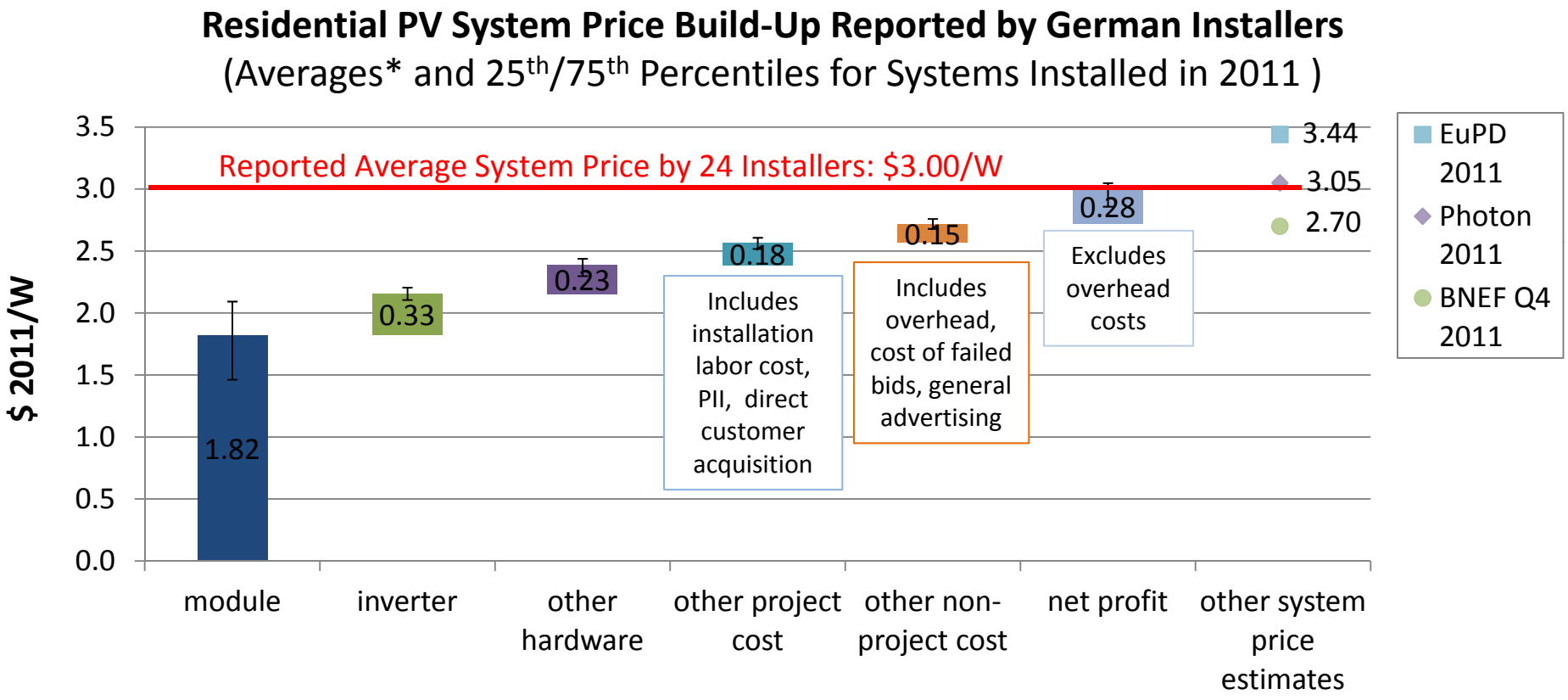
- Most are small-volume installers
  - Plurality of respondents completed 10-49 residential systems in 2011
  - Median value: 26 systems completed in 2011
- Installer-average residential system sizes (total MW divided by total systems) are relatively large*
  - Half of installers have average residential system sizes >8 kW





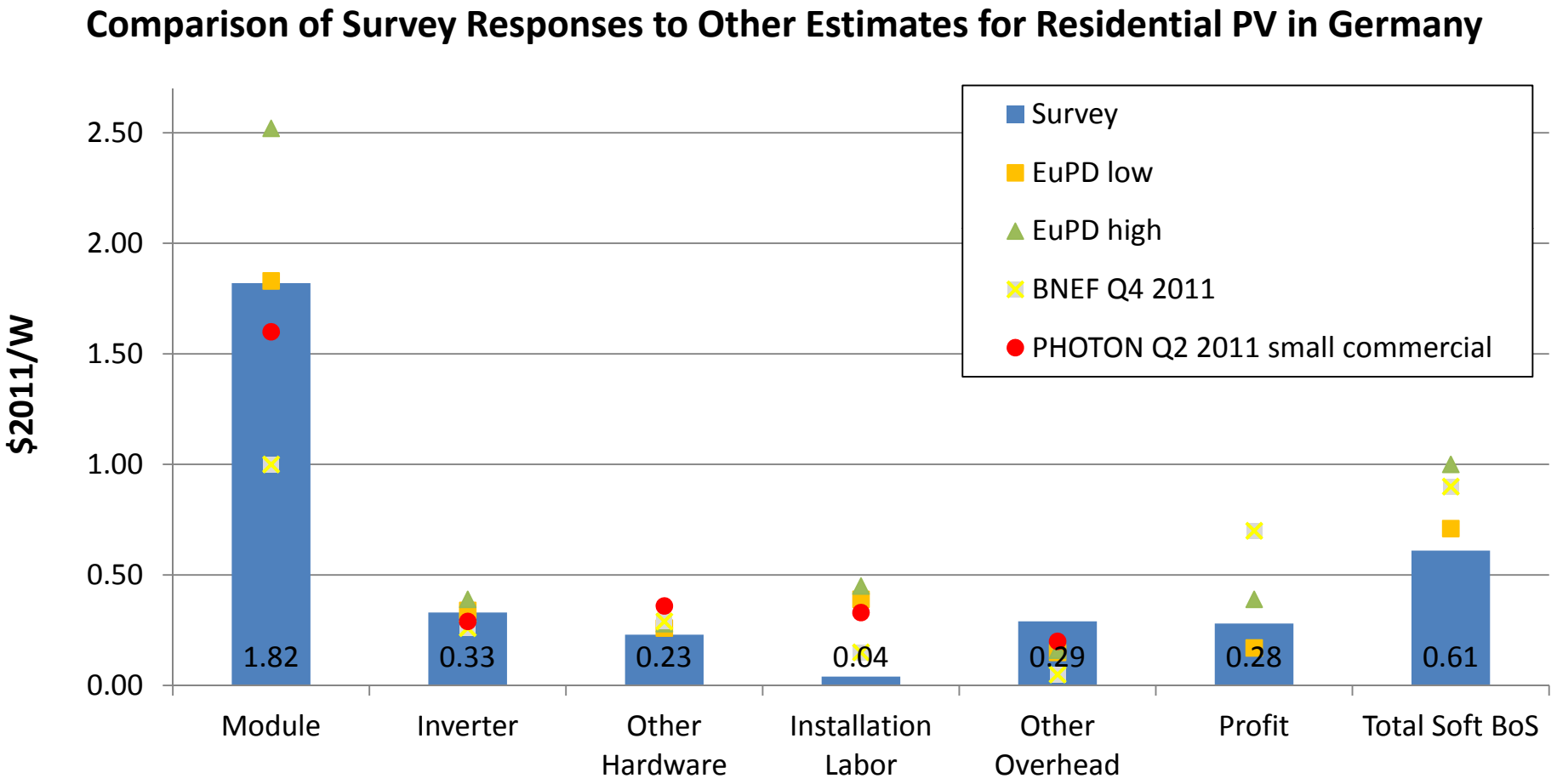
* Note that two respondents may have over-reported MWs installed, leading to a large calculated average system size (potentially due to multi-family houses)

Total Soft BoS Costs + Profit Represent Roughly $0.62/W or 20% of System Price



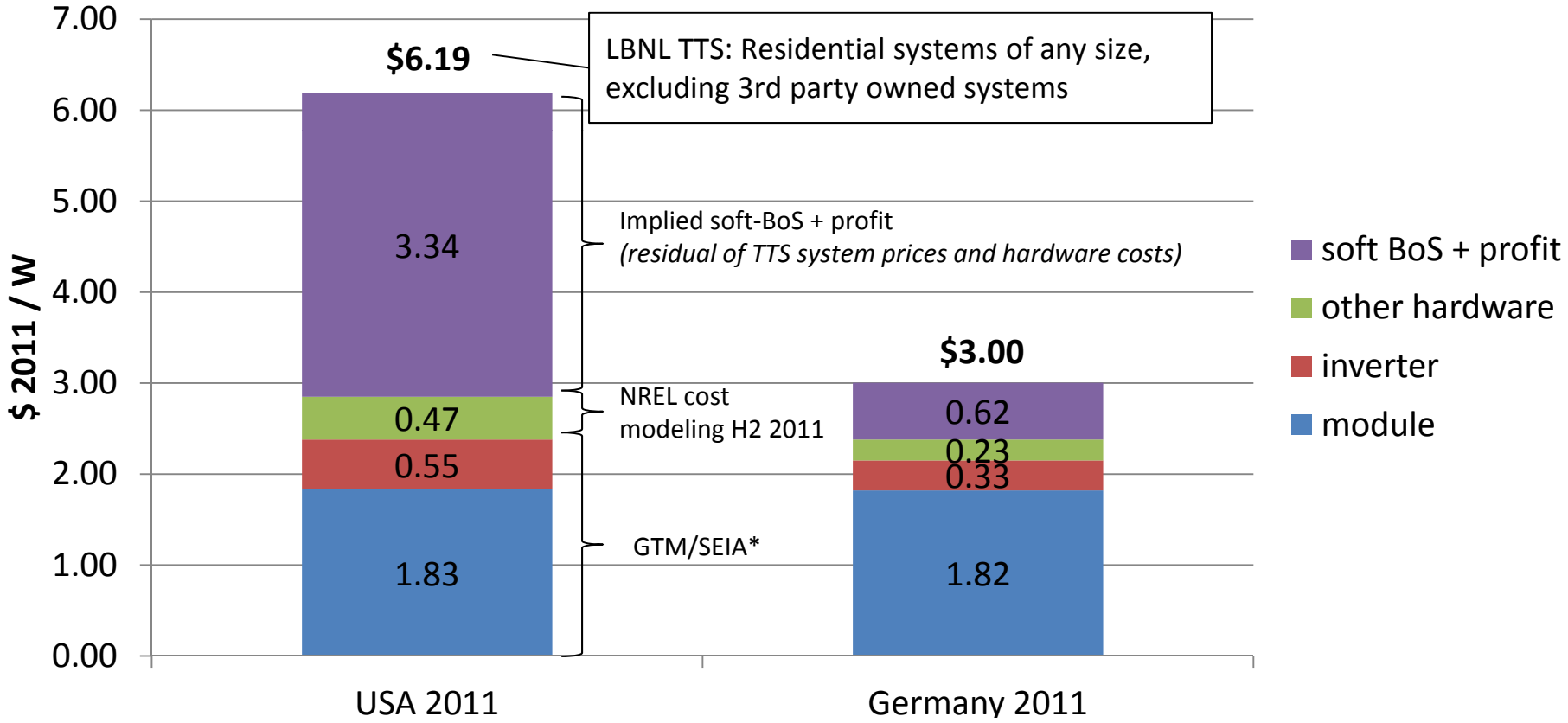
*** *Notes:*** Survey results are summarized in terms of the average of responses across survey respondents, weighted by each respondent's reported 2011 residential capacity installed. This chart summarizes responses to the survey question asking installers to identify the average price of residential systems sold in 2011, and to allocate that price across the categories identified along the x-axis.

Reported Installation Labor Costs and Profit Are Lower than Estimates Reported Elsewhere



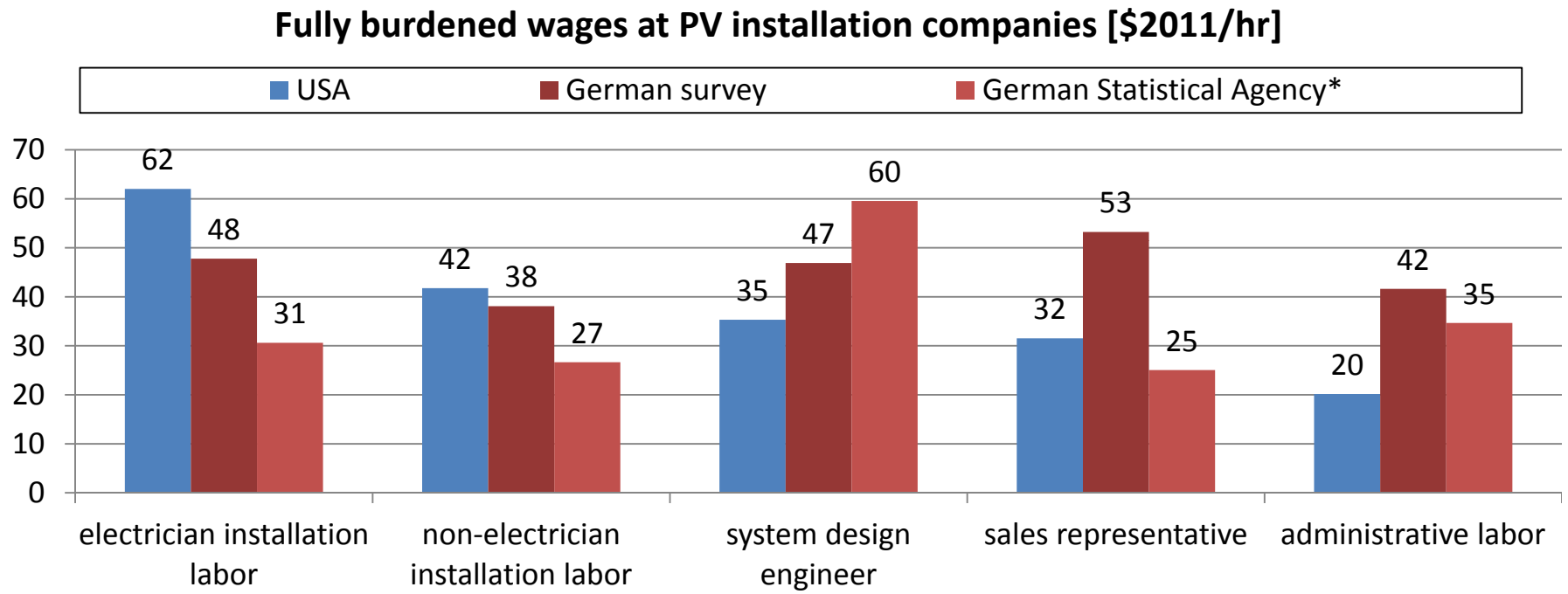
Soft Costs for Residential PV in Germany Are ~$2.7/W Lower Than in the U.S.

Total soft costs for residential PV in Germany, including margin, are just 19% of the implied soft costs for U.S. residential PV ($0.62/W vs. $3.34/W)



* **Notes:** US module and inverter prices are based on average factory gate prices for Q4 2010-Q3 2011 as reported by GTM/SEIA with an adder of 10% to account for supply chain costs. Inverter efficiency assumed to be 85%.

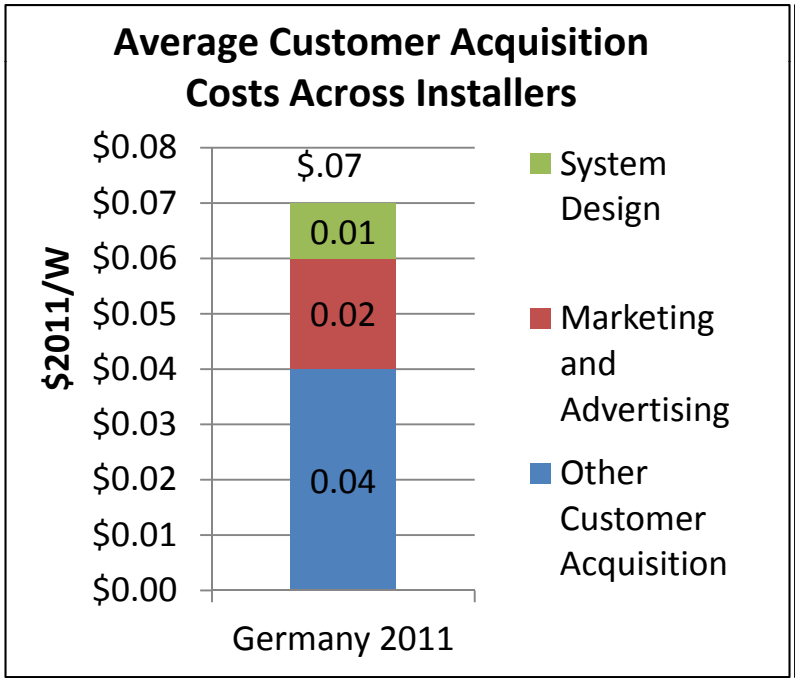
Labor Rates Are Higher in Germany Than in the U.S. for Some Functions, but Lower for Others

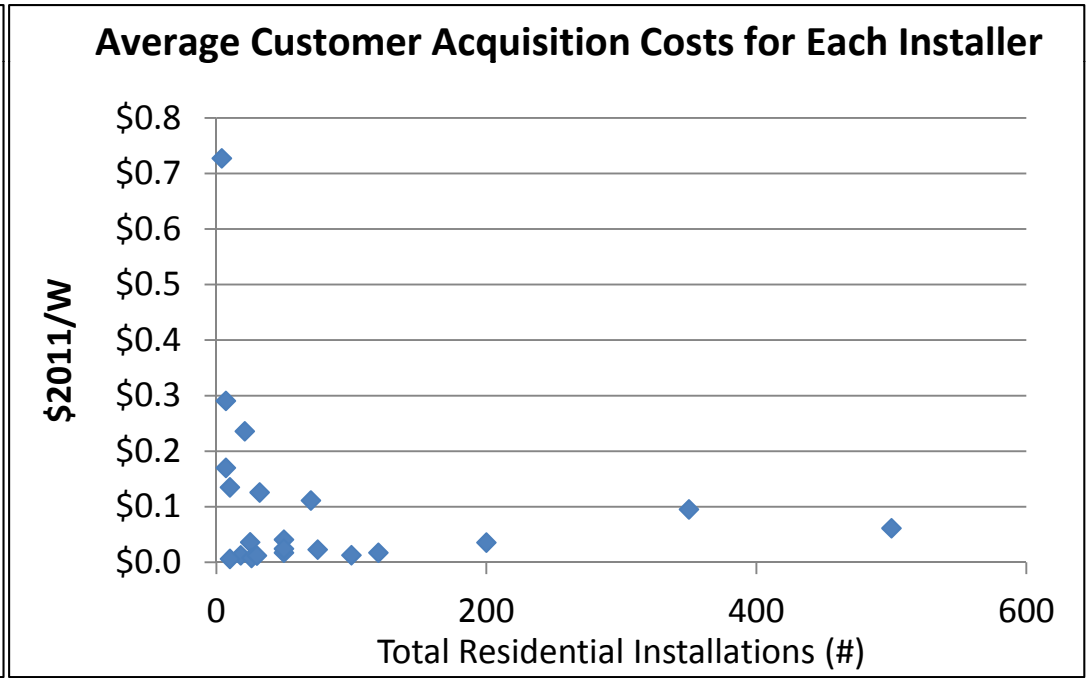


- The results that follow this slide rely on German wage rates derived from the survey
- In the above graphic, data from the German statistical agency are also shown for comparison (these data cover all sectors, so are not specific to PV)
- U.S. labor rates are from RS Means (as used by NREL cost modeling team and as used in NREL BoS survey analysis for the U.S.)

Residential Customer Acquisition Costs Average $0.07/W in Germany

- Most respondents reported customer acquisition costs <$0.15/W; several small-volume installers reported somewhat higher costs
- On average, customer acquisition labor includes 3 hrs/system for sales representative and 2 hrs/system for design engineer

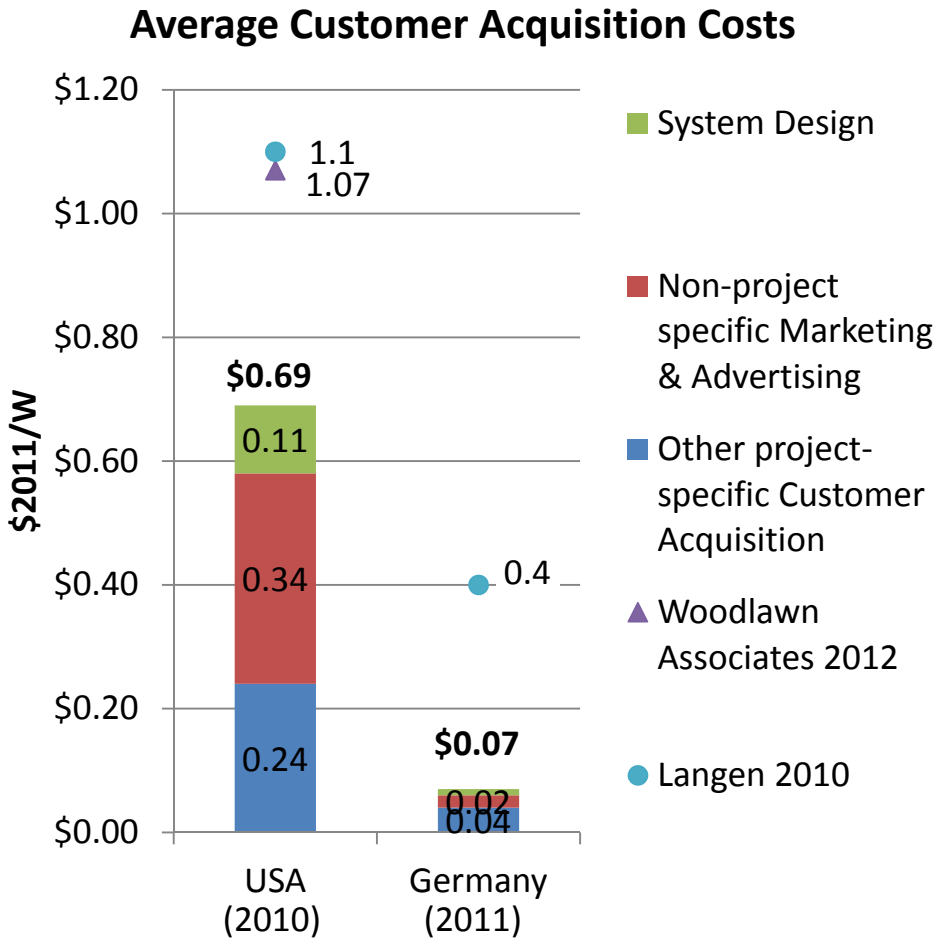




Notes: Other Customer Acquisition Costs include such items as: sales calls, site visits, travel time to and from the site, contract negotiation, bid preparation. Marketing & Advertising and Other Customer Acquisition costs are based on reported annual expenditures, while System Design costs are based on reported labor hours and wages for system design engineering.

Customer Acquisition Costs in Germany Are $0.6/W Less Than in the U.S.

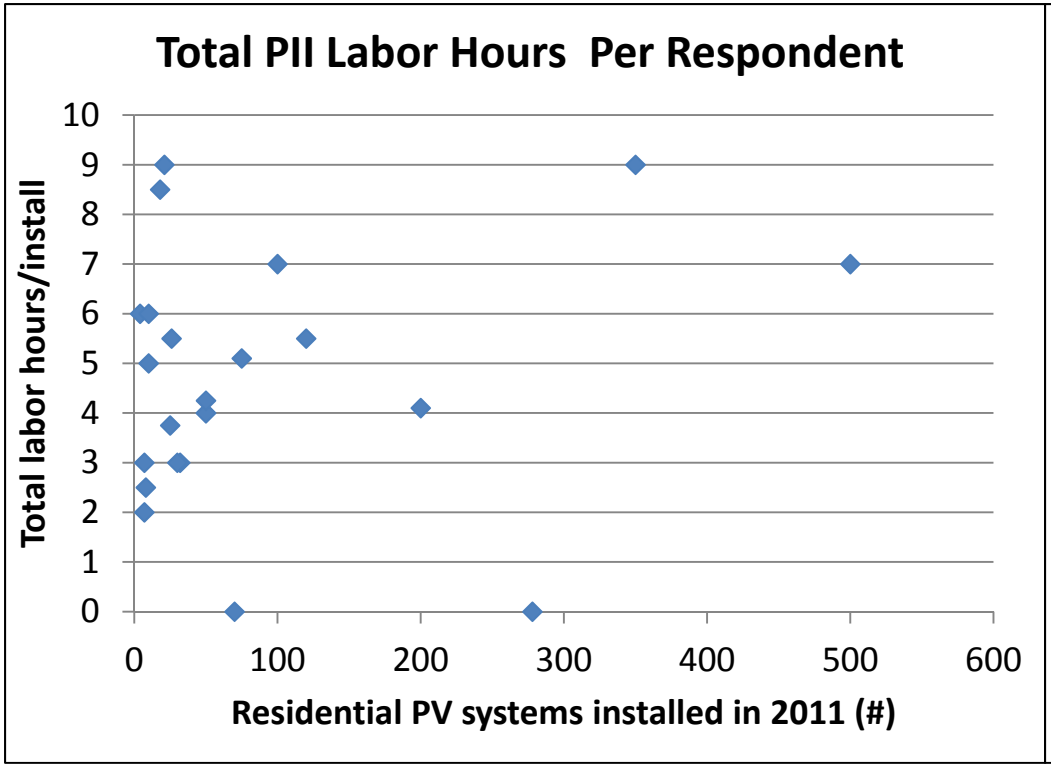
- Mean bid success rate is slightly lower in the US (30% in US vs. 40% in Germany)
- German installers leverage partnerships with equipment manufacturers
- Langen (2010) points to simpler and more certain value proposition in Germany (i.e., FiT), installer learning, and critical mass for word of mouth

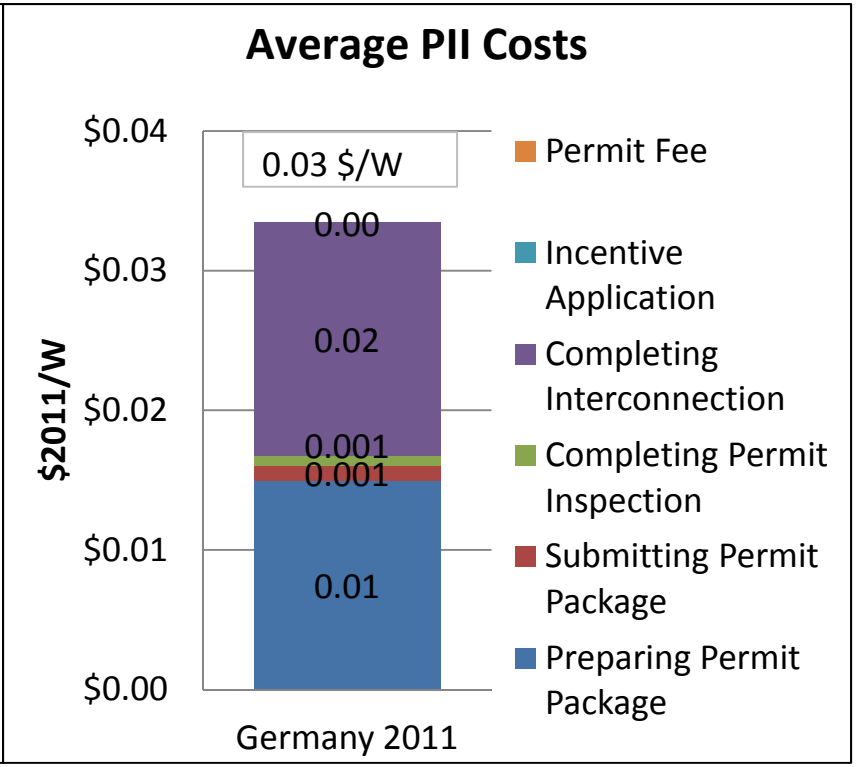


Notes: Bar chart of US customer acquisition costs derives from NREL survey of U.S. installers (Ardani et al. 2012).

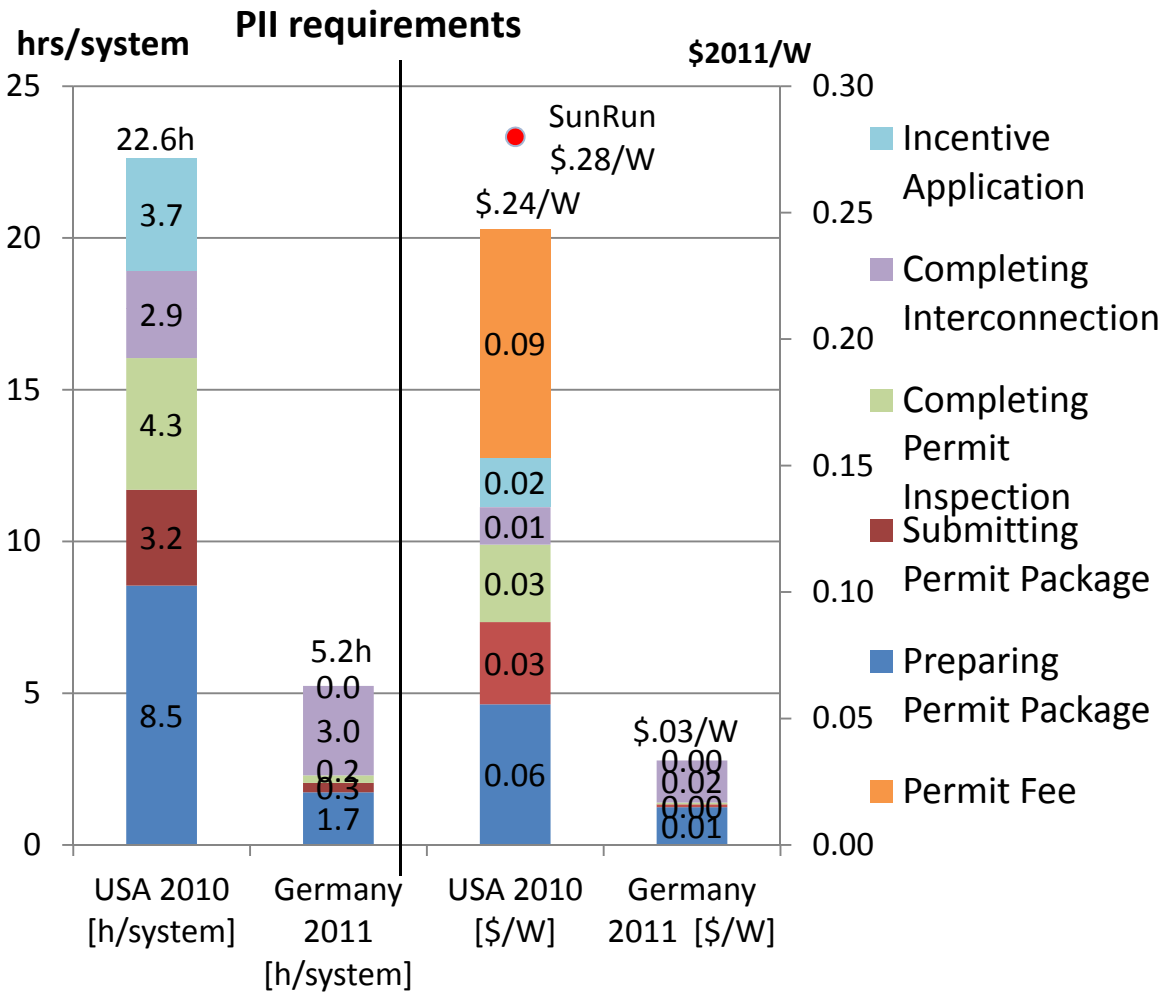
PII Costs Are Negligible for Residential PV in Germany

- Total PII costs of $0.03/W on average
- Fewer than 10 hours of labor required for all PII activities, and no fee
  - Average labor requirement of 5 hrs (confirmed by PV legal survey, lowest for all European countries)
  - Permit requests and incentive application are done online; usually no permit inspection required





PII Costs Account for Roughly $0.2/W of the German-U.S. PV Price Gap



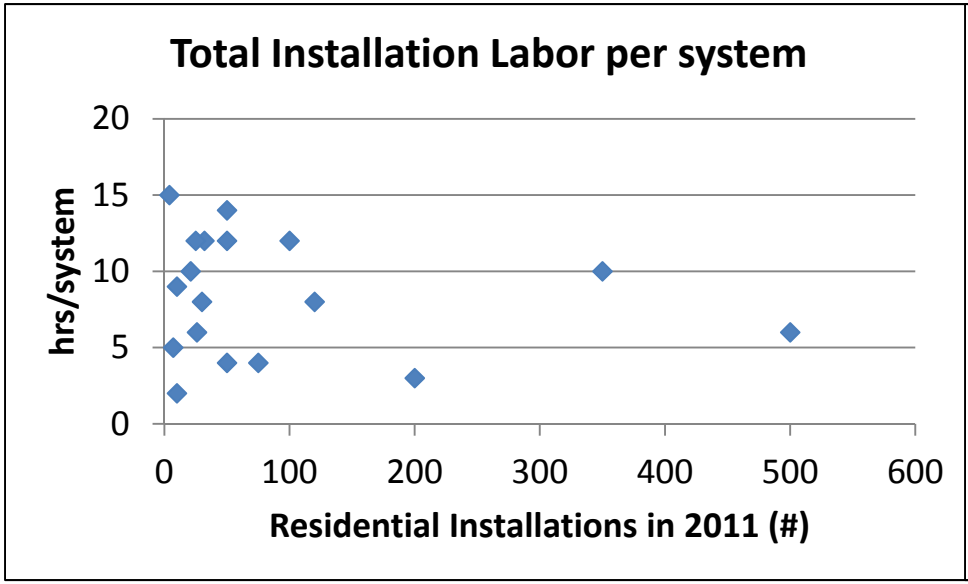
Differences due to both PII labor costs and permit fee

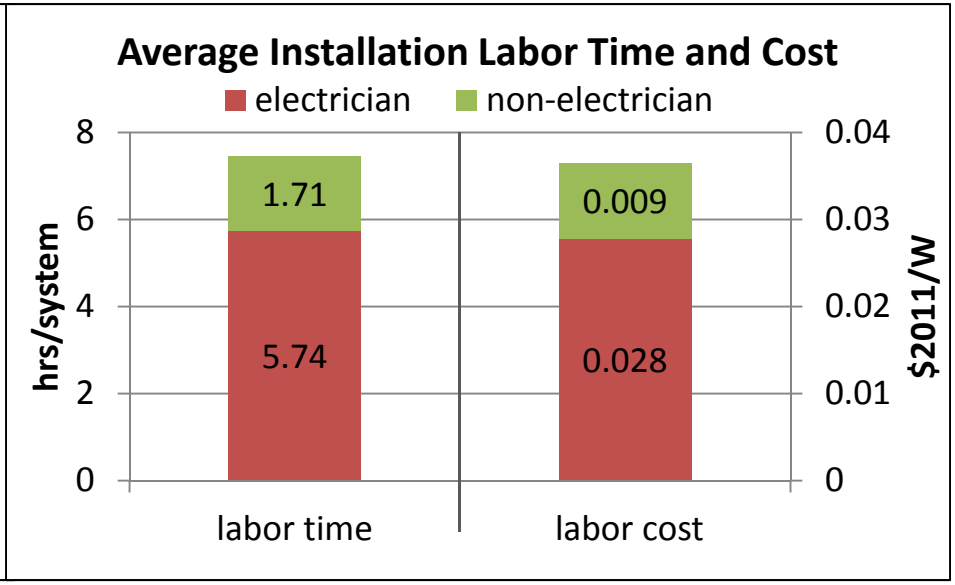
- PII labor costs are $0.12/W lower in Germany*
- Remainder of gap ($0.09/W) is associated with permit fee (assuming an average of $430 per system in the U.S.)
- Langen (2010) estimates PII costs for the US at $.80/W, and Germany at $.10/W
- SunRun (2011) figure of $.50/W includes sales & marketing costs & variations in building requirements

* Fully-burdened labor rates assumptions: 70% design engineer and 30% administrative labor; averaging $41/hr for Germany (based on survey questions) vs. $26/hr for the U.S. (based on RS Means data, per NREL PV cost modeling team)

German Installers Report Surprisingly Low Installation Labor Requirements

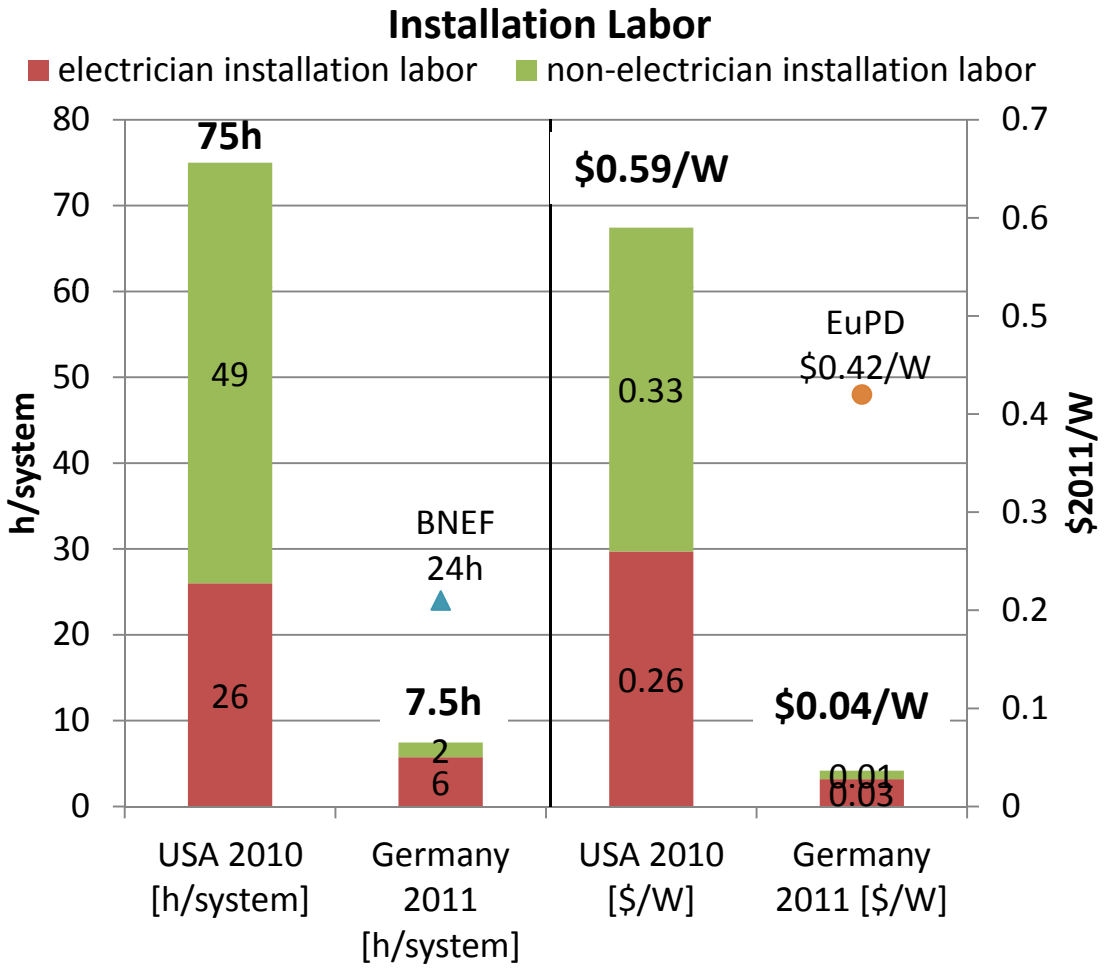
- All 24 respondents indicated fewer than 15 hrs/system required for installation labor (electrician + construction labor)
  - *Averaged* 7.5 hrs/system, equating to less than $0.04/W, based on reported fully-burdened wage rates*
- This is much lower than other estimates; warrants further examination
  - BNEF estimates 24 person-hours for 3kW system; EuPD estimates $0.39-$0.45/W





* Fully-burdened German labor rates: electrician wage = $48/hr, non-electrician wage = $38/hr (averages of survey responses)

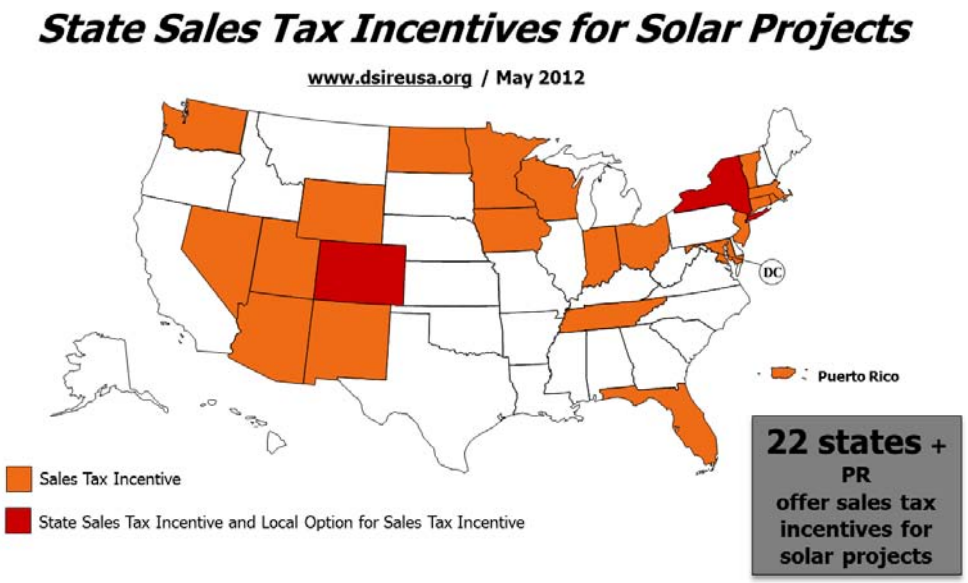
Not Surprisingly Then, Installation Labor Costs Are Much Lower Than in the U.S.



- Survey results indicate that, on average, systems are installed roughly 10 times faster in Germany than in the U.S. (7.5 vs. 75 hours per system)
- Leading to total installation labor costs that are $0.55/W lower than in the U.S.
- Other estimates of labor costs for German PV also show savings relative to the U.S., though differential is smaller → warrants further investigation

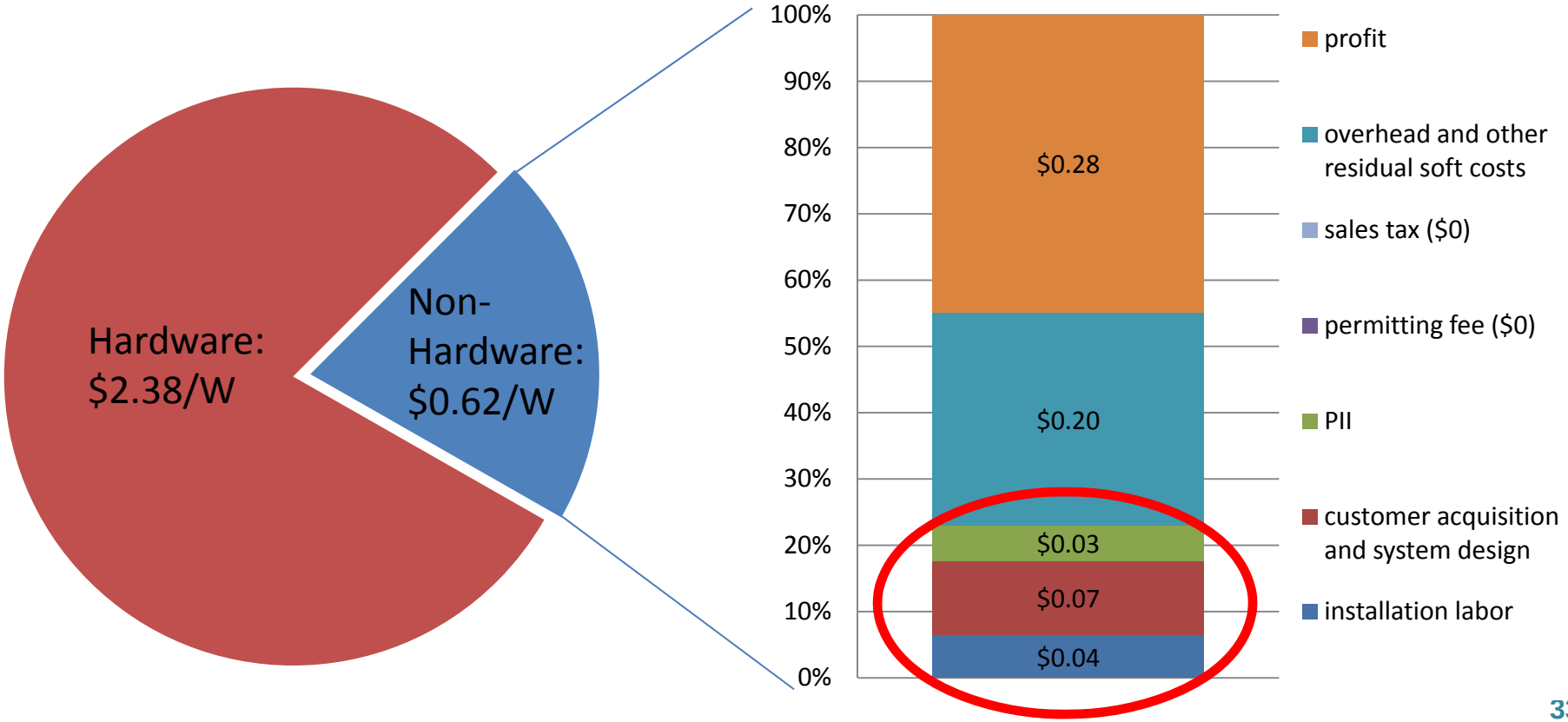
Nationwide Sales Tax Exemptions in Germany Further Reduce Soft Costs

- Survey respondents confirmed that German residential PV systems are effectively exempt from revenue taxes/ sales taxes/ value added taxes
  - Regular tax rate of 19% can be exempted either via “Kleinunternehmer” or “Vorsteuererstattungs” clause
- In the U.S., 23 states assess sales tax on residential PV systems, usually 4-8% of system prices, as do many local governments
- Given the spatial distribution of PV systems, and accounting for sales tax exemptions in some states, state and local sales taxes added $0.21/W to the price of residential PV in the U.S. in 2011

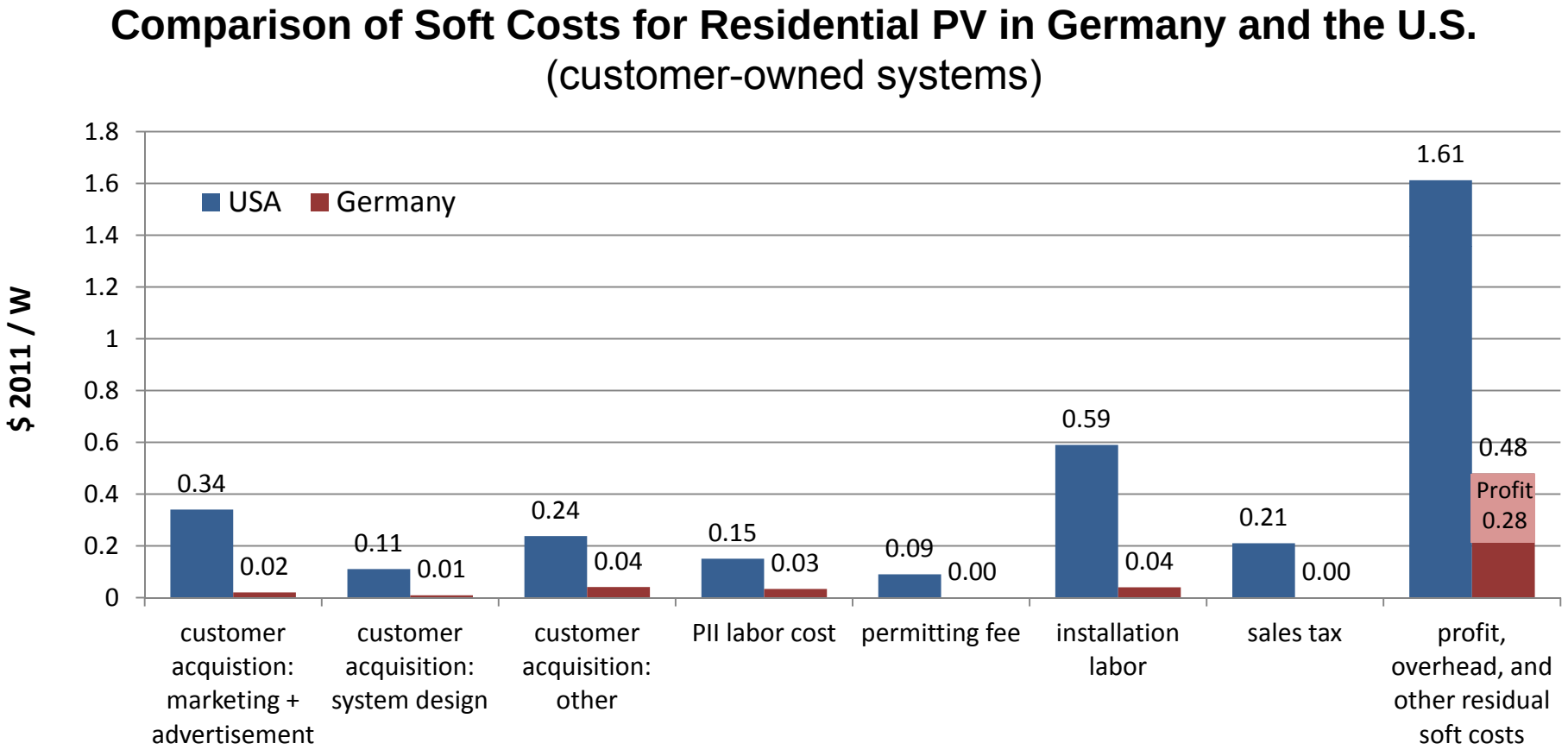


PII, Customer Acquisition, and Installation Labor Total Just $0.14/W for Residential PV in Germany

For residential PV in Germany, PII, customer acquisition, and installation labor are estimated to represent **23%** of all non-hardware costs (which primarily consists of overhead and profit) and **5%** of the total system price.

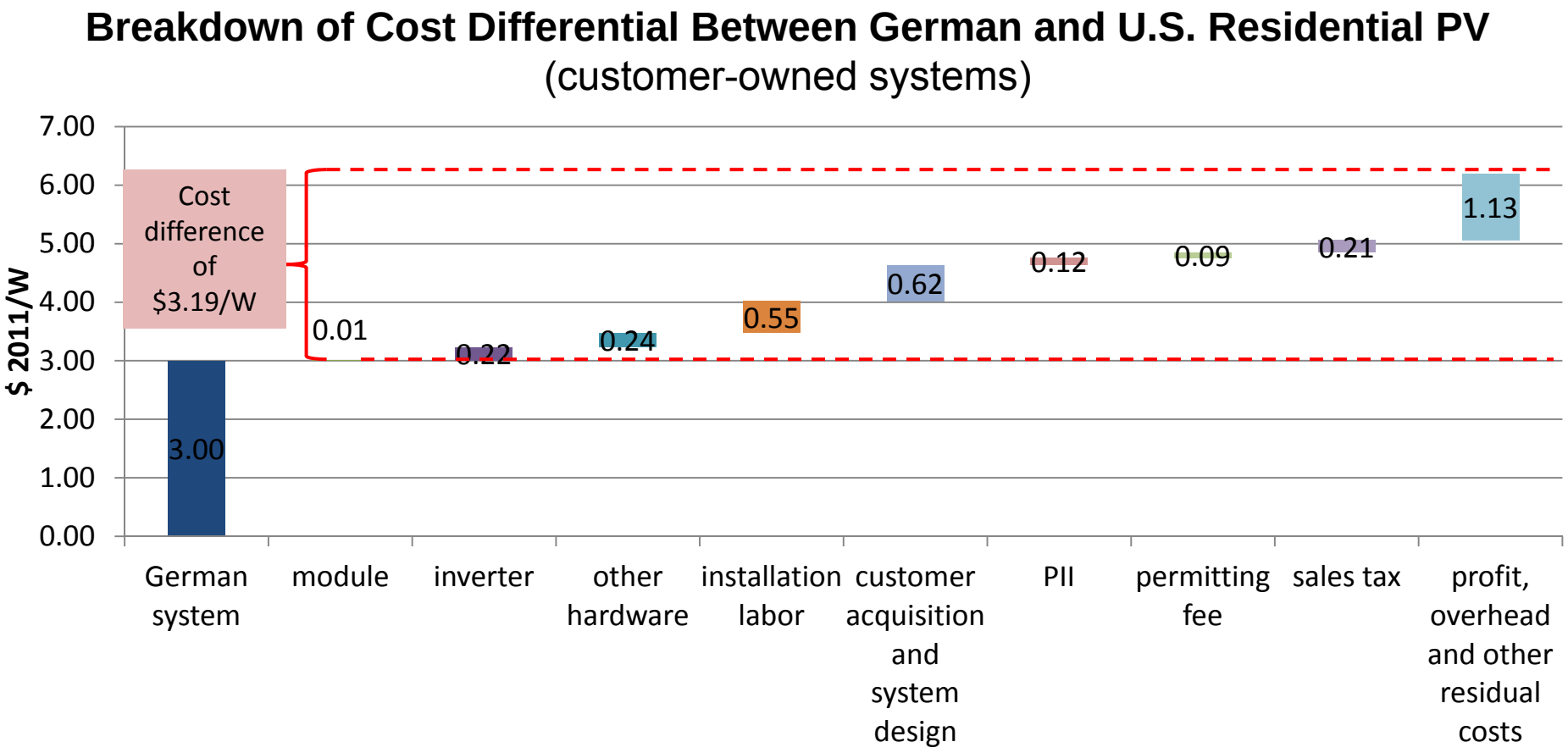


Summary of Soft Cost Differences for Residential PV in the U.S. and Germany



Notes: "Profit, overhead, and other residual soft costs" is calculated as a residual term based on the difference between total soft costs and the sum of the individual business process costs quantified through the German and U.S. installer surveys. This residual term includes such items as property-related expenses (rent, utilities, etc.), inventory-related costs, additional insurances and fees, and general administrative costs.

Summary of Soft Cost Differences for Residential PV in the U.S. and Germany



Notes: "Profit, overhead, and other residual soft costs" is calculated as a residual term based on the difference between total soft costs and the sum of the individual business process costs quantified through the German and U.S. installer surveys. This residual term includes such items as property-related expenses (rent, utilities, etc.), inventory-related costs, additional insurances and fees, and general administrative costs.

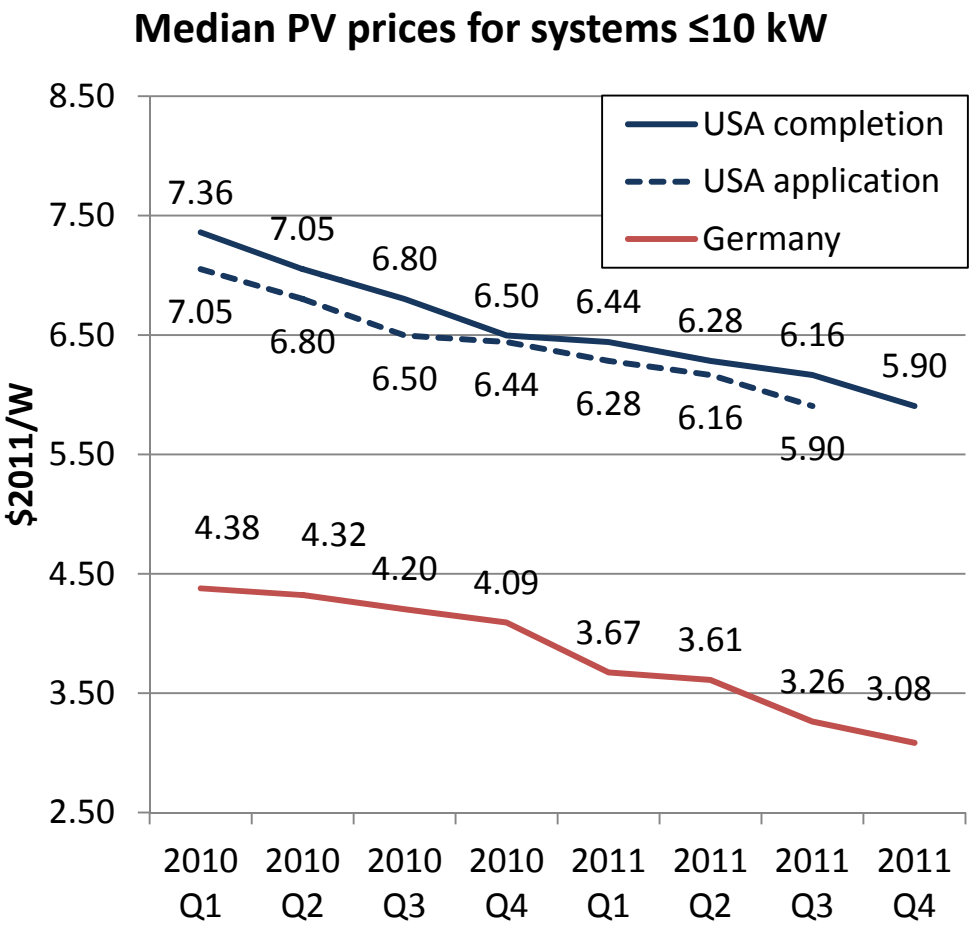
Secondary Analyses

Questions Explored through Secondary Data Sources

1. To what extent do shorter project development times in Germany contribute to the apparent price gap (i.e., quicker pass-through of module price declines)?
2. Are residential PV systems larger in Germany, leading to potential price differences due to economies of scale at the system level?
3. Are a larger percentage of German systems comprised of Chinese modules than in the U.S.?

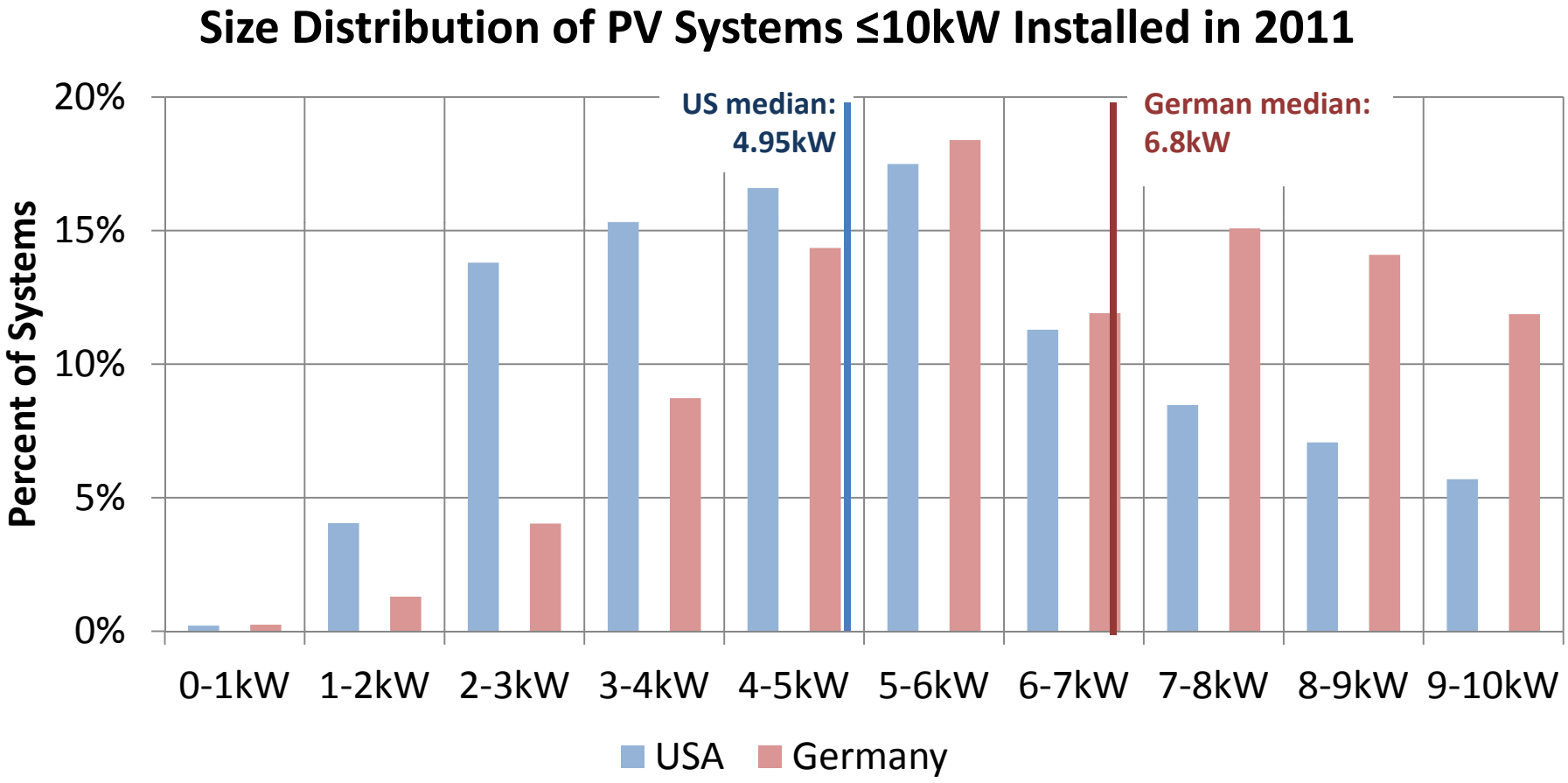
Note: Item 2 is not additive to the differences in specific business process costs presented previously, but rather helps to explain those differences (e.g. larger system sizes in Germany might partly explain why marketing costs, on a per Watt basis, are lower).

Longer U.S. Project Development Time Contributes to Apparent Price Gap



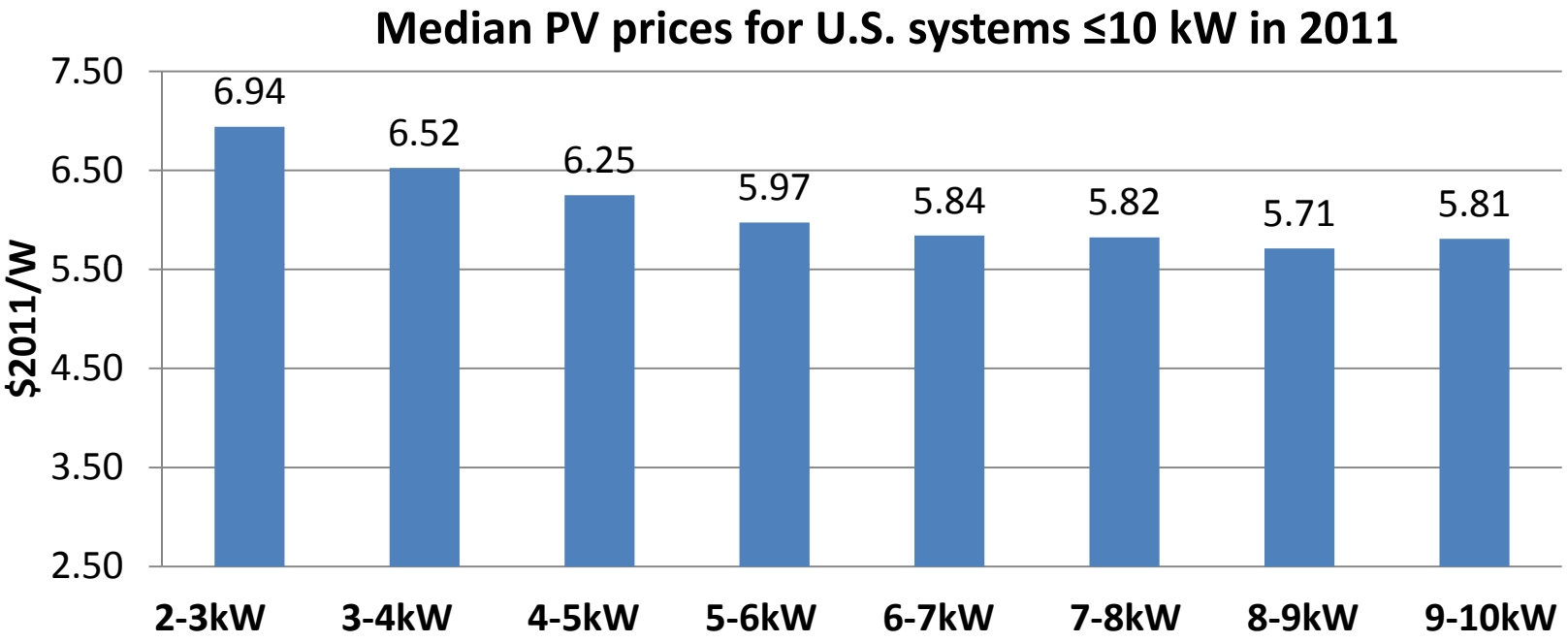
- Based on TTS data and German survey responses, residential projects take 126 days to develop in the U.S. vs. 35 days in Germany
- When comparing German and U.S. system prices based on installation date, some of the difference is due to the longer development time in the U.S., i.e., German system pricing is effectively "shifted" one quarter relative to the U.S.
- In Q4 2011, this effect contributes ~$0.18/W ($3.26 minus $3.08) to the apparent price gap
- Larger or smaller impacts in other quarters, depending on speed of price declines

German Residential Systems Are Generally Larger Than U.S. Systems



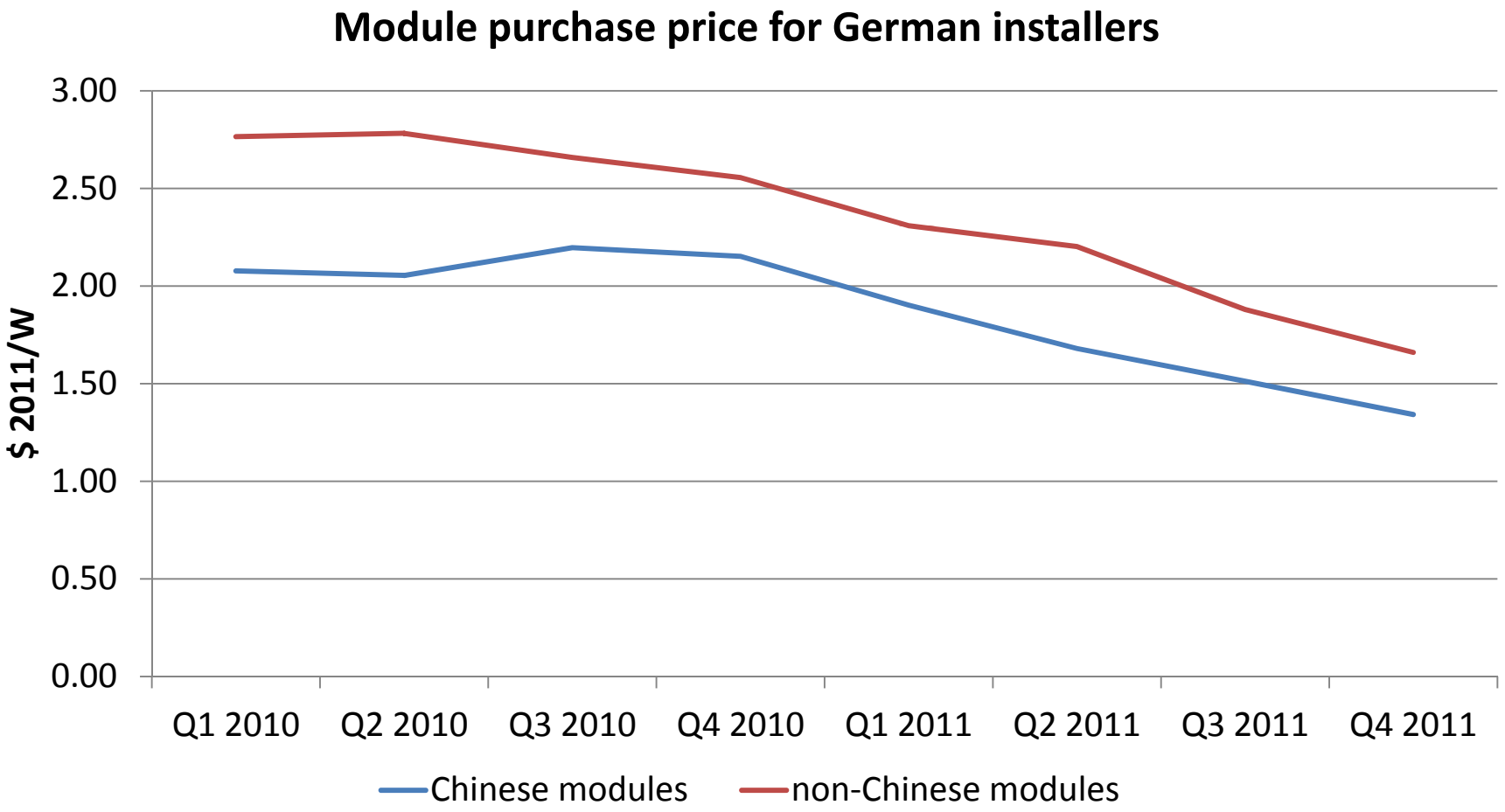
US data based on TTS; German data reflects all grid-connected PV systems (in front + behind the meter) as collected by the Federal Grid Agency (Bundesnetzagentur, BNetzA)

If the Size Distribution of U.S. Residential Systems Were the Same as in Germany, Median Prices Would Be $0.15/W Lower



- Applying the price distribution shown here for U.S. systems to the system size distribution for German systems (shown on the previous slide) yields a median system price that is $0.15/W lower than the actual median price for the 2011 U.S. systems in the TTS data sample ($6.21/W)

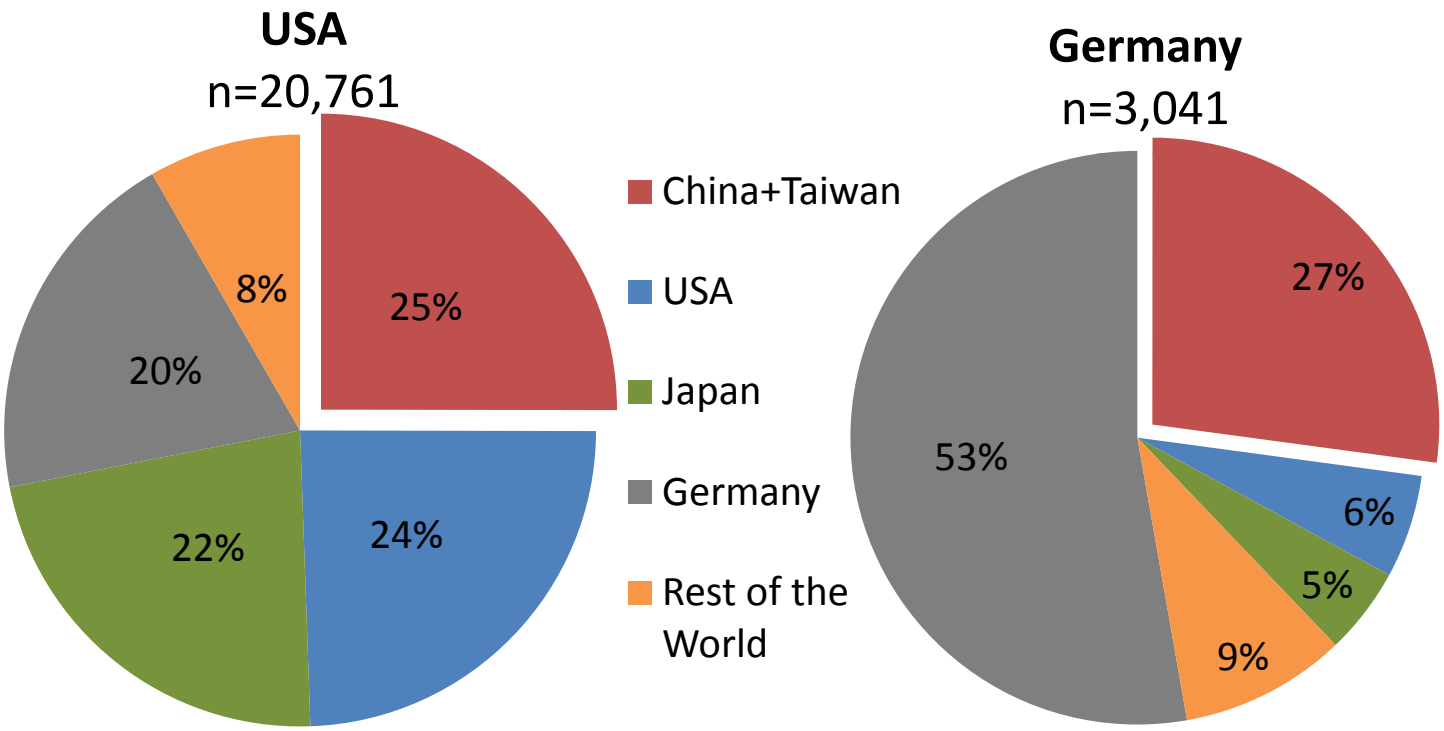
Installer Purchase Prices for Chinese Modules Are Lower than for Non-Chinese Modules



Data source: EuPD

The Price Gap Is Not Due to Differences in Chinese Module Market Share

Share of module manufacturers by country of headquarters for *customer-owned ≤10kW systems* in 2011



Chinese modules are cheaper, but…

Among customer owned systems ≤10 kW, the U.S. and Germany had similar shares of Chinese modules*

Thus differences in Chinese module market share do not contribute significantly to the German-U.S. price gap for ≤10 kW customer-owned systems

Sources: TTS, EuPD

* Third-party owned systems in the U.S. have a higher share of Chinese modules (see BNEF 2012, for example), but for the purpose of assessing the price gap in this analysis, we focus specifically on customer-owned systems.

Summary of Findings from Survey of German Installers

- Total non-hardware costs for residential PV in Germany are **~$2.70/W** lower than in the U.S.
- **Customer acquisition costs** average just $0.07/W in Germany, or roughly **$0.60/W lower** than in the U.S.
- **Installation labor** requirements reportedly average 7.5 hours for German systems, leading to **$0.55/W lower** costs than in the U.S. (though these survey data diverge substantially from other estimates)
- **PII** processes require 10 hours of labor, on average, in Germany, with no permitting fee, resulting in PII costs roughly **$0.20/W lower** than in the U.S.
- German residential systems are exempt from **sales/value-added tax**, while U.S. systems are subject to an average sales tax of roughly **$0.20/W** (accounting for sales tax exemptions in many U.S. states)
- The remaining gap in soft costs between Germany in the U.S. (**~$1.15/W**) is associated with **overhead, profit, and other residual soft costs** not captured in the categories above

Summary of Findings from Secondary Analysis

- Shorter project development times in Germany contribute to apparent price gap (e.g., **~$0.2/W** effect for Q4 2011 installations)
- Residential PV systems are larger in Germany (partly due to differences in policy design), benefitting from economies of scale (**$0.15/W** effect)
  - Not additive to the differences in soft costs presented previously, but rather helps to explain those differences (e.g. larger system sizes in Germany are partly why marketing costs, on a per Watt basis, are lower)
- Market share of Chinese modules is similar for *customer-owned* residential systems in Germany and U.S., and thus does not contribute to price gap

Suggestions for Further Research

- Initiate a more refined analysis of overhead costs and margins among installers
- Better understand the pricing decision of installers and competition between installers (i.e., degree of “value-based pricing”)
- Clarify installation labor hours in Germany and the U.S. and potential efficiency gains
- Compare supply-chain margins between the two countries and average prices paid by installers for modules and inverters
- Assess the role of FIT policies in Germany in stimulating price reductions and potential implications for U.S. solar policy

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Questions?

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Download LBNL Electricity Markets & Policy Publications:

http://eetd.lbl.gov/ea/emp/re.html

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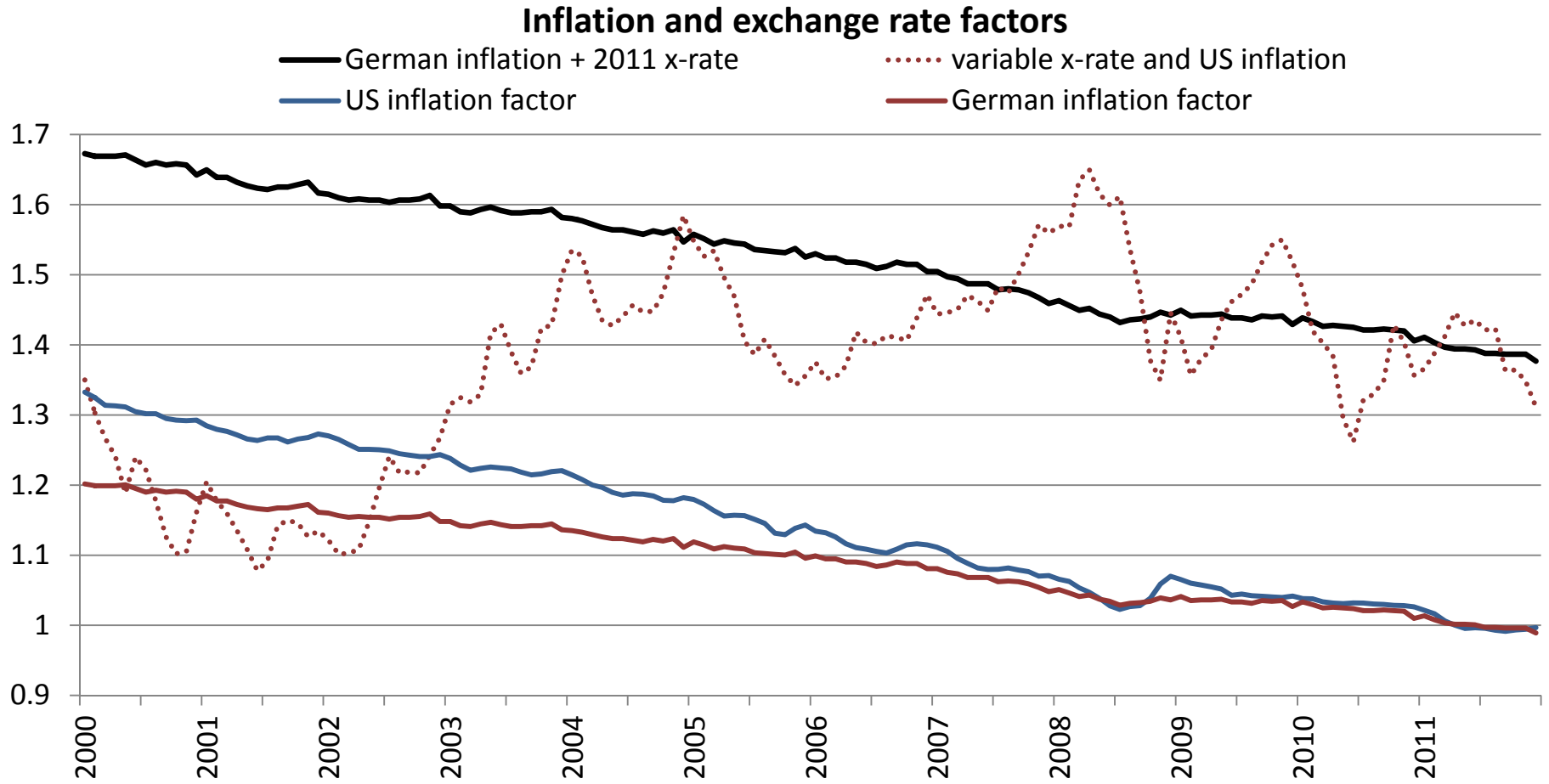
Appendix: Currency Conversion



First German prices were normalizes for 2011 €, which were then converted to $ using the average exchange rate of the year 2011 of $1.39/€.